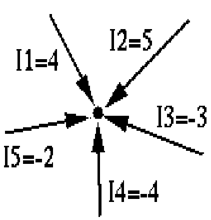
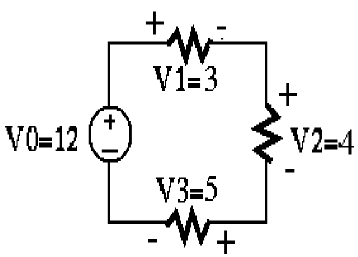
# Unit-2
# Electrical Circuit Analysis

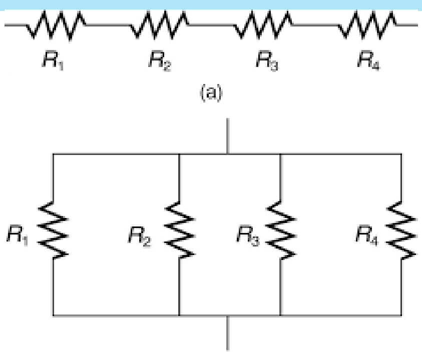

Prepared by:
Jigar Sarda
M & V Patel Department of Electrical Engineering
CHARUSAT
jigarsarda.ee@charusat.ac.in

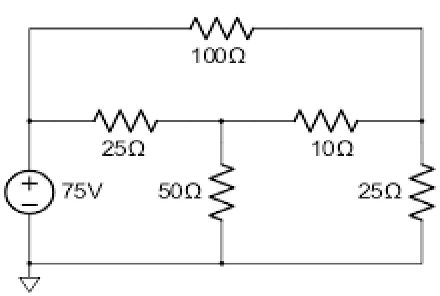



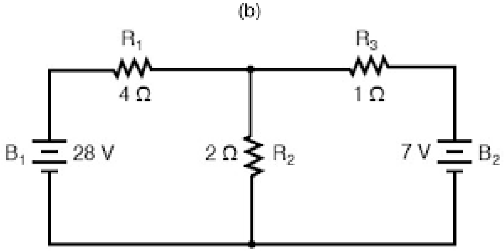

I1+I2+I3+I4+I5=0

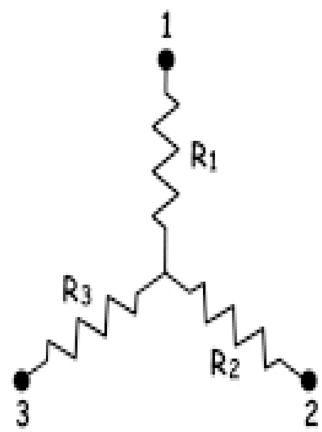


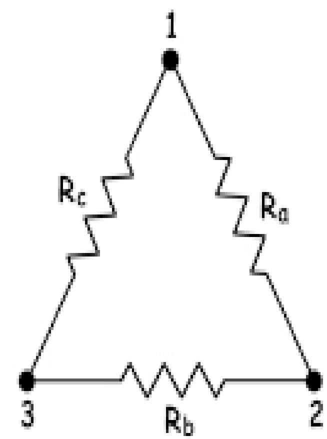

V0+V1+V2+I3=0



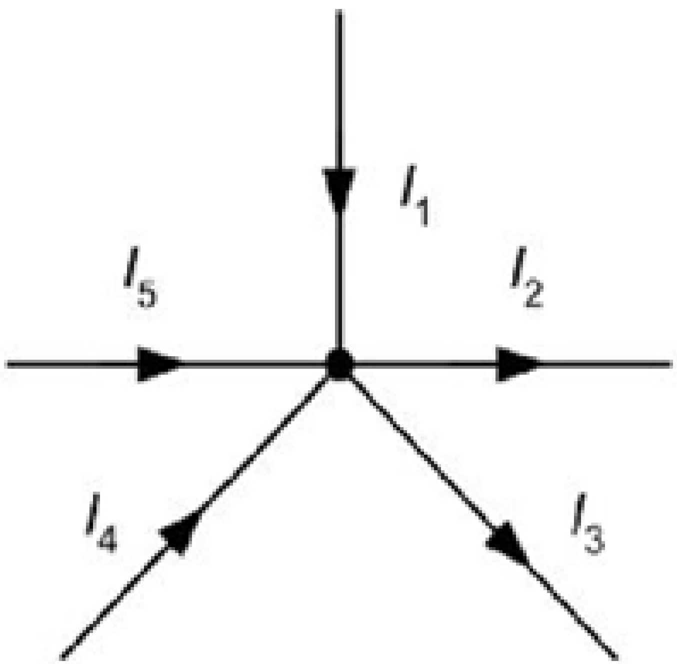



# Content

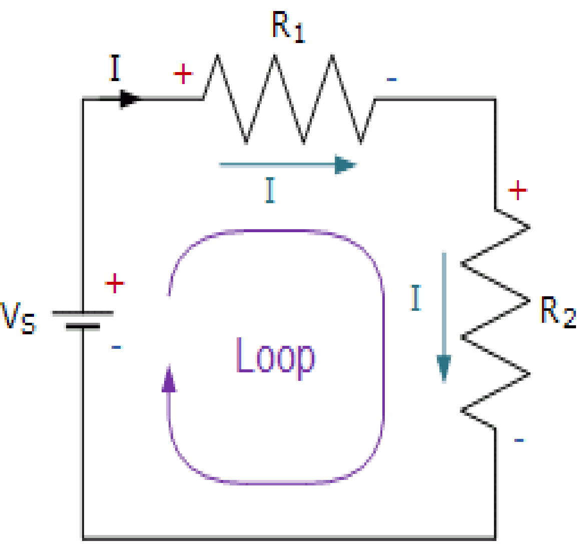
# Kirchhoff's Current Law (KCL)




$$I_1 - I_2 - I_3 + I_4 + I_5 = 0$$

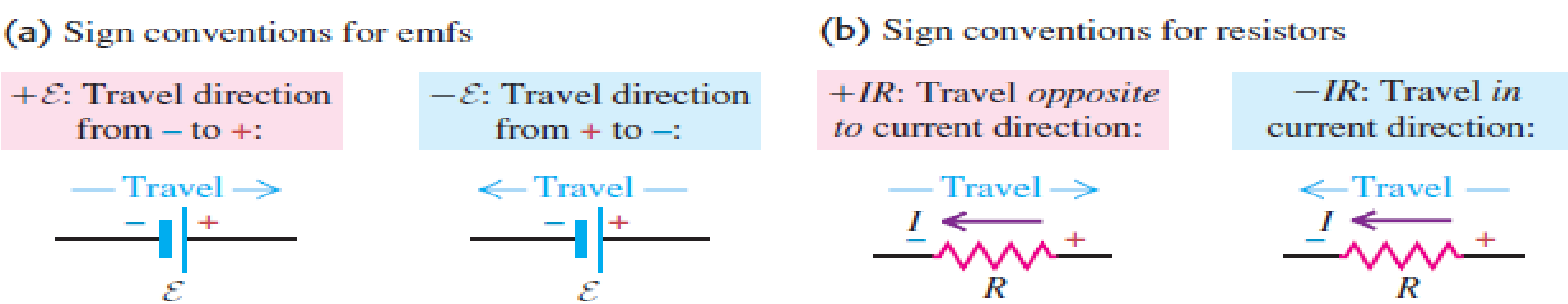
- KCL states that "In an electrical circuit, at any point of time, the algebraic sum of the current in all the conductors meeting at any point is zero."
- In other words, whenever two or more conductors meet at a point then the sum of the current flowing towards the junction point is equal to the sum of current flowing away from it.
- If the current entering into a junction are assigned a positive sign, then the current leaving the junction will be assigned a negative sign.

# Kirchhoff's Voltage Law (KVL)



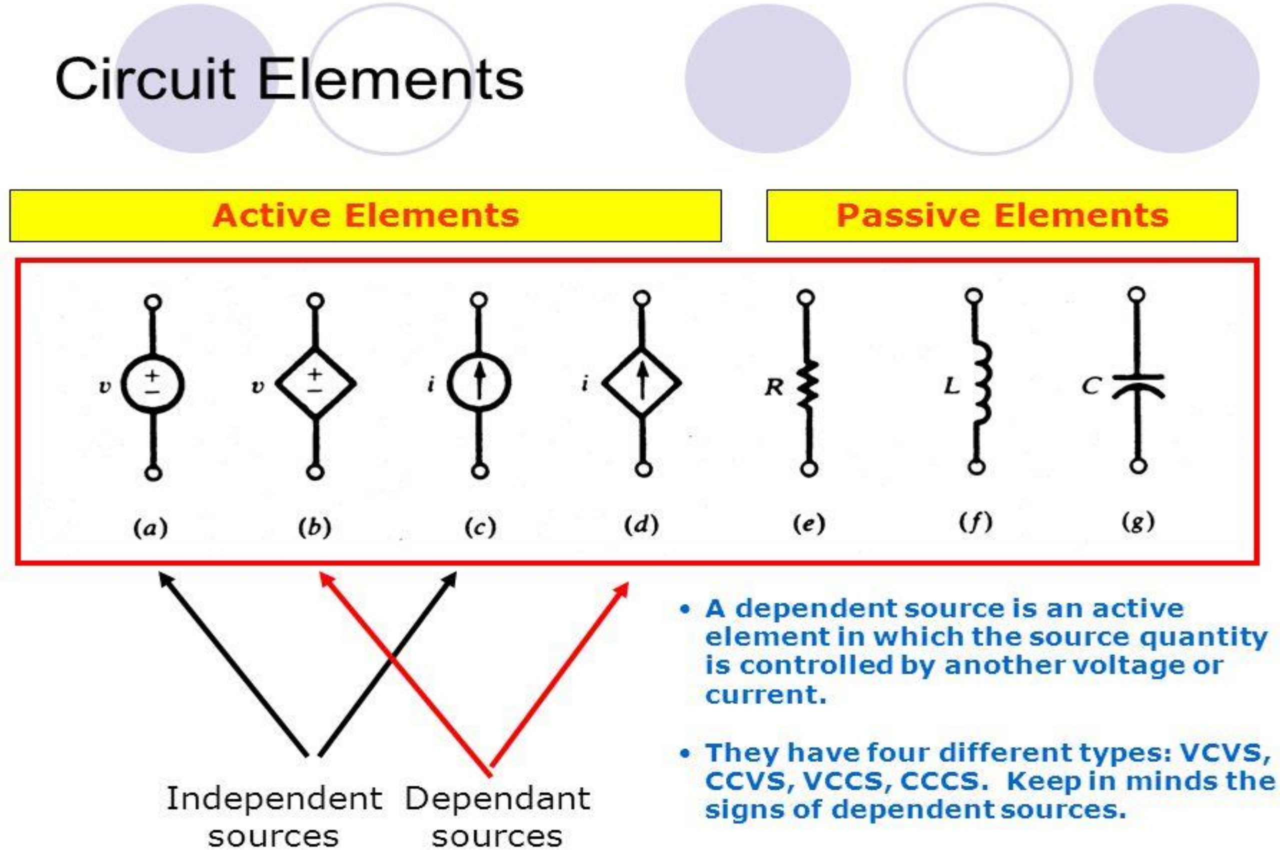

- KVL states that "the algebraic **sum** of the potential differences in any loop must be equal to zero as: $\Sigma V = 0$."
- Since the two resistors, $R_1$ and $R_2$ are wired together in a series connection, they are both part of the same loop so the same current must flow through each resistor.
- Thus the voltage drop across resistor, R1 = I*R1 and the voltage drop across resistor, R2 = I*R2 giving by KVL:

$$\boxed{V_S + (-IR_1) + (-IR_2) = 0}$$

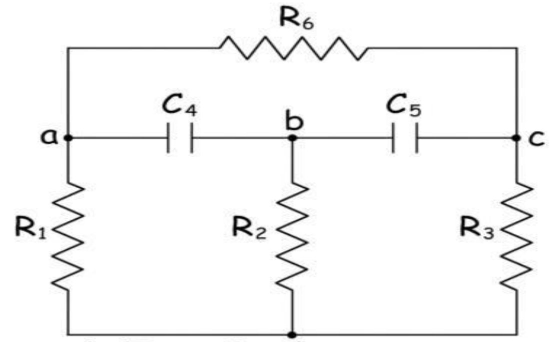


# Definition

1. **Element:-** It is a mathematical model of two terminal electrical device which can be completely characterized by its voltage and current.



2. **Network:-** The interconnection of two or more elements called an electric network.




Network (Fig - 1)

3. **Circuit:-** If a network contains at least one closed path, it is called and electric circuit.
4. **Active element:-** The element which is capable of **delivering an average power greater than zero to some external device over an infinite time** interval is called an active element.

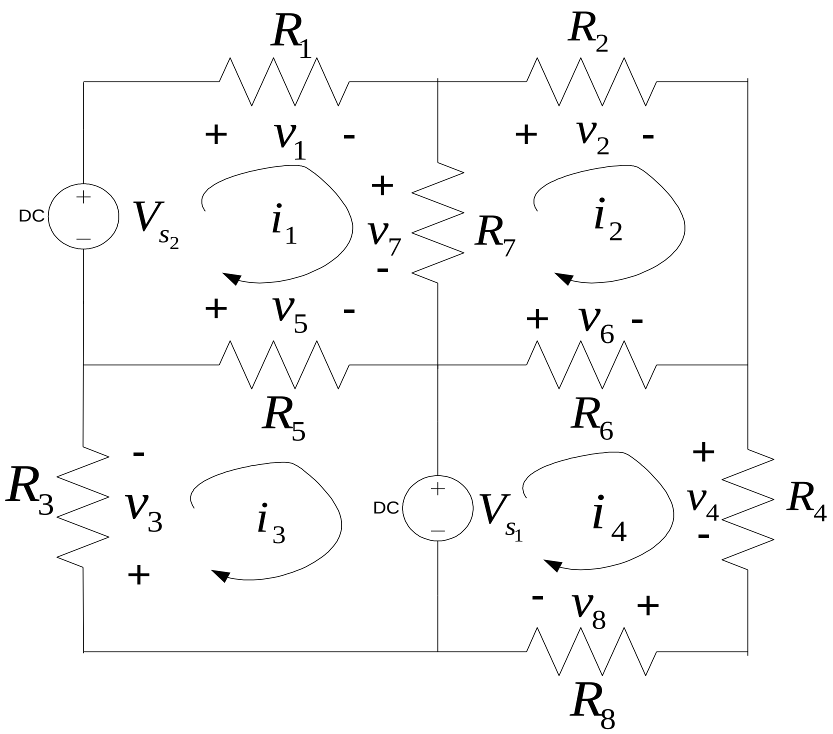
5. **Passive element:-** The element which is **capable only of receiving power** is called passive element.
6. **Node:-** The point at **which two or more elements** are connected together is called as node.
7. **Junction:-** It is a point where **three or more elements** are connected together.
8. **Branch:-** A section or portion of a **network or circuit which lies between two junction points** is called as branch.
9. **Loop:- Any closed path in** a network is called loop.
10. **Mesh:-** It is the most **elementary form of a loop and cannot be further divided into other loops**.

# Mesh Analysis

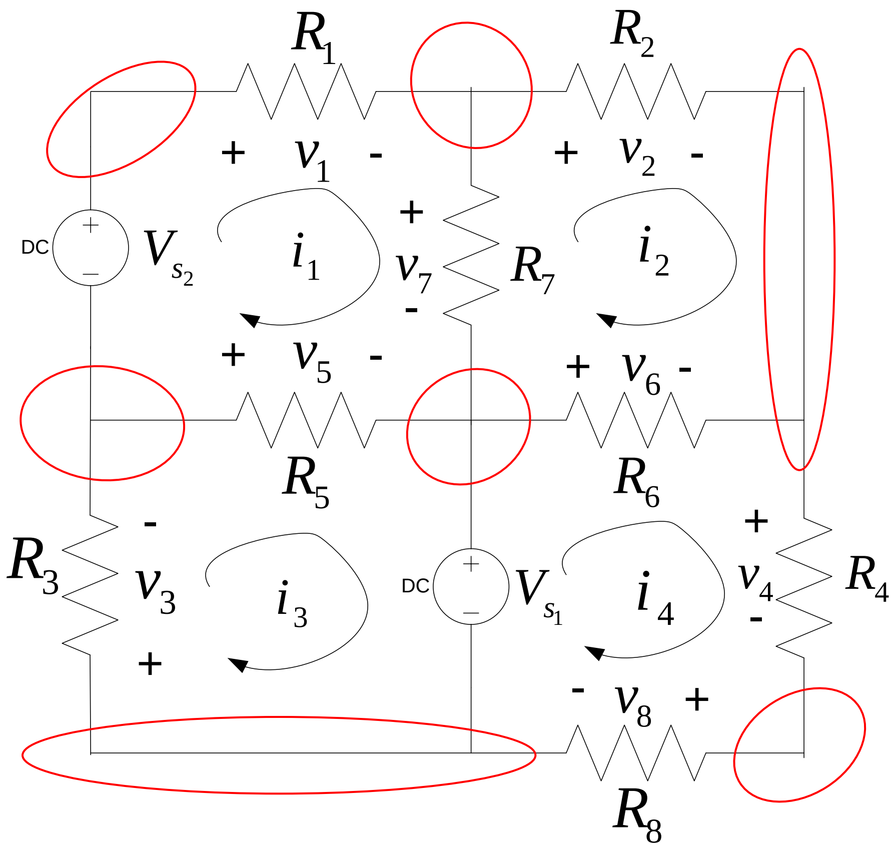
- Mesh analysis applies KVL to find unknown currents.
- It is only applicable to planar circuits (a circuit that can be drawn on a plane with no branches crossing each other).
- A mesh is a loop that does not contain any other loops.
- The current through a mesh is known as the mesh current.
- Assume for simplicity that the circuit contains only voltage sources.

# Mesh Analysis Steps

1. Assign mesh currents $i_1$, $i_2$, $i_3$, … $i_l$, to the $l$ meshes,
2. Apply KVL to each of the $l$ meshes and use Ohm's law to express the voltages in terms of the mesh currents,
3. Solve the $l$ resulting simultaneous equations to find the mesh currents.



# Example



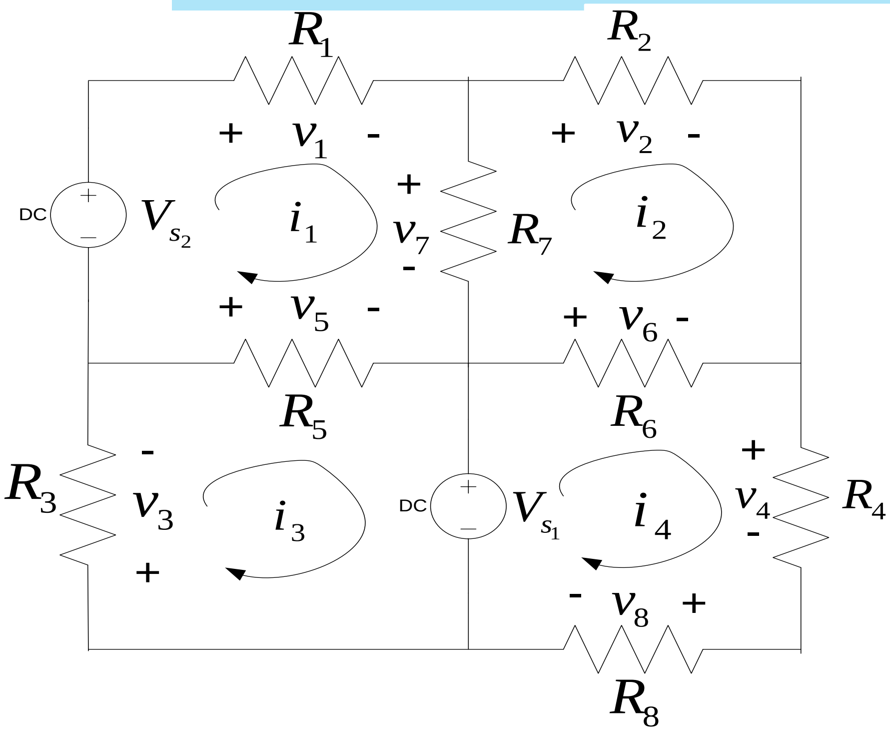

Number of nodes, $n$ = **7**

Number of loops, $l$ = **4**

Number of branches, $b$ = **10**

$$l = b - n + 1$$

# Example




Apply KVL to each mesh

Mesh 1: $$-V_{s_2} + v_1 + v_7 - v_5 = 0$$

Mesh 2: $$v_2 - v_6 - v_7 = 0$$

Mesh 3: $$v_5 + v_{s_1} + v_3 = 0$$

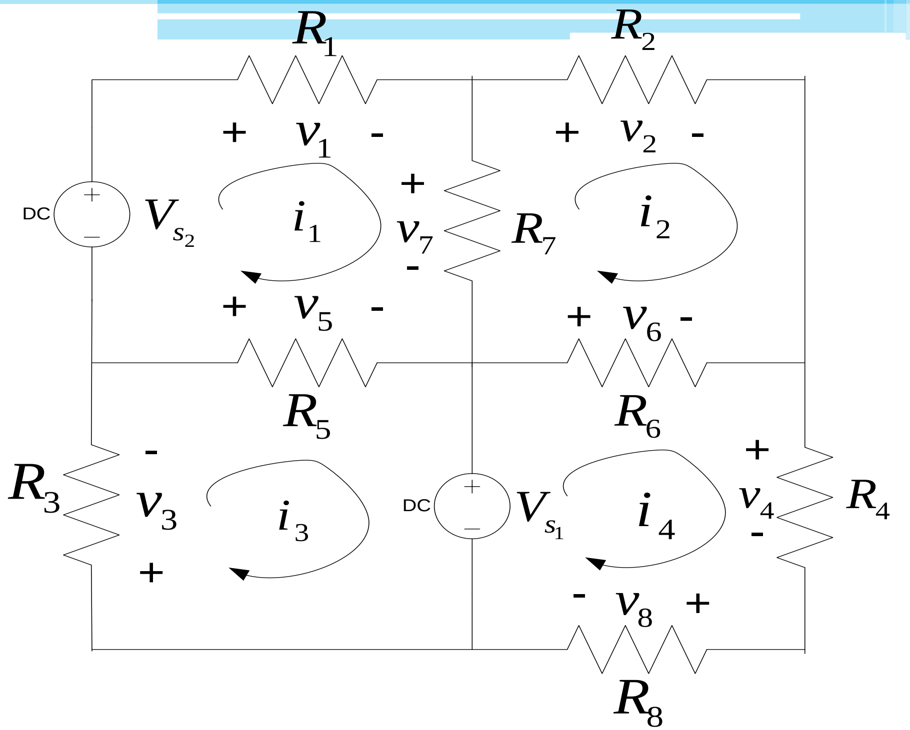
Mesh 4: $$v_4 + v_8 - V_{s_1} + v_6 = 0$$

Mesh 1: $$-V_{s_2} + v_1 + v_7 - v_5 = 0$$

Mesh 2: $$v_2 - v_6 - v_7 = 0$$

Mesh 3: $$v_5 + v_{s_1} + v_3 = 0$$

Mesh 4: $$v_4 + v_8 - V_{s_1} + v_6 = 0$$




Express the voltage in terms of the mesh currents:

Mesh 1: $$-V_{s_2} + i_1 R_1 + (i_1 - i_2) R_7 + (i_1 - i_3) R_5 = 0$$

Mesh 2: $$i_2 R_2 + (i_2 - i_4) R_6 + (i_2 - i_1) R_7 = 0$$

Mesh 3: $$(i_3 - i_1) R_5 + V_{s_1} + i_3 R_3 = 0$$

Mesh 4: $$i_4 R_4 + i_4 R_8 - V_{s_1} + (i_4 - i_2) R_6 = 0$$

Mesh 1: $$-V_{s_2} + i_1 R_1 + (i_1 - i_2)R_7 + (i_1 - i_3)R_5 = 0$$

Mesh 2: $$i_2 R_2 + (i_2 - i_4)R_6 + (i_2 - i_1)R_7 = 0$$

Mesh 3: $$(i_3 - i_1)R_5 + V_{s_1} + i_3 R_3 = 0$$

Mesh 4: $$i_4 R_4 + i_4 R_8 - V_{s_1} + (i_4 - i_2)R_6 = 0$$

Mesh 1: $$(R_1 + R_5 + R_7)i_1 - R_7 i_2 - R_5 i_3 = V_{s_2}$$

Mesh 2: $$-R_7 i_1 + (R_2 + R_6 + R_7)i_2 - R_6 i_4 = 0$$

Mesh 3: $$-R_5 i_1 + (R_3 + R_5)i_3 = -V_{s_1}$$

Mesh 4: $$-R_6 i_2 + (R_4 + R_6 + R_8)i_4 = V_{s_1}$$

Mesh 1: $(R_1+R_5+R_7)i_1 - R_7 i_2 - R_5 i_3 = V_{s_2}$

Mesh 2: $-R_7 i_1 + (R_2+R_6+R_7)i_2 - R_6 i_4 = 0$

Mesh 3: $-R_5 i_1 + (R_3+R_5)i_3 = -V_{s_1}$

Mesh 4: $-R_6 i_2 + (R_4+R_6+R_8)i_4 = V_{s_1}$

$$\begin{pmatrix} R_1+R_5+R_7 & -R_7 & -R_5 & 0 \\ -R_7 & R_2+R_6+R_7 & 0 & -R_6 \\ -R_5 & 0 & R_3+R_5 & 0 \\ 0 & -R_6 & 0 & R_4+R_6+R_8 \end{pmatrix}\begin{pmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{pmatrix} = \begin{pmatrix} V_{s_2} \\ 0 \\ -V_{s_1} \\ V_{s_1} \end{pmatrix}$$

$$\begin{pmatrix} R_1+R_5+R_7 & -R_7 & -R_5 & 0 \\ -R_7 & R_2+R_6+R_7 & 0 & -R_6 \\ -R_5 & 0 & R_3+R_5 & 0 \\ 0 & -R_6 & 0 & R_4+R_6+R_8 \end{pmatrix} \begin{pmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{pmatrix} = \begin{pmatrix} V_{s_2} \\ 0 \\ -V_{s_1} \\ V_{s_1} \end{pmatrix}$$

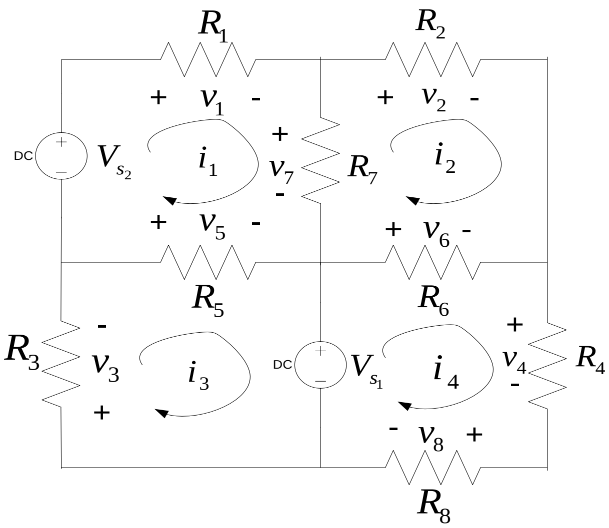
$$\mathbf{Ri} = \mathbf{v}$$

$\mathbf{R}$ is an $l \times l$ *symmetric* resistance matrix

$\mathbf{i}$ is a $1 \times l$ vector of mesh currents

$\mathbf{v}$ is a vector of voltages representing “known” voltages

# Writing the Mesh Equations by Inspection




$$\begin{pmatrix} R_1+R_5+R_7 & -R_7 & -R_5 & 0 \\ -R_7 & R_2+R_6+R_7 & 0 & -R_6 \\ -R_5 & 0 & R_3+R_5 & 0 \\ 0 & -R_6 & 0 & R_4+R_6+R_8 \end{pmatrix}\begin{pmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{pmatrix} = \begin{pmatrix} V_{s_2} \\ 0 \\ -V_{s_1} \\ V_{s_1} \end{pmatrix}$$

•The matrix **R** is symmetric, $r_{kj} = r_{jk}$ and all of the off-diagonal terms are negative or zero.

The $r_{kk}$ terms are the sum of all resistances in mesh $k$.

The $r_{kj}$ terms are the negative sum of the resistances common to BOTH mesh $k$ and mesh $j$.

The $v_k$ (the $k^{th}$ component of the vector **v**) = the algebraic sum of the independent voltages in mesh $k$, with voltage rises taken as positive.

# Using Cramer's Rule to Solve a System of Three Equations

Consider the following set of linear equations

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 = b_1$$
$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 = b_2$$
$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 = b_3$$

# Using Cramer's Rule to Solve a System of Three Equations

The system of equations above can be written in a matrix form as:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

# Using Cramer's Rule to Solve a System of Three Equations

Define

$$[A]=\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

$$[x]=\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \; and \; [B]=\begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

If $D \neq 0$, then the system has a unique solution as shown below (Cramer's Rule).

$$x_1=\frac{D_1}{D}, \quad x_2=\frac{D_2}{D}, \quad x_3=\frac{D_3}{D}$$

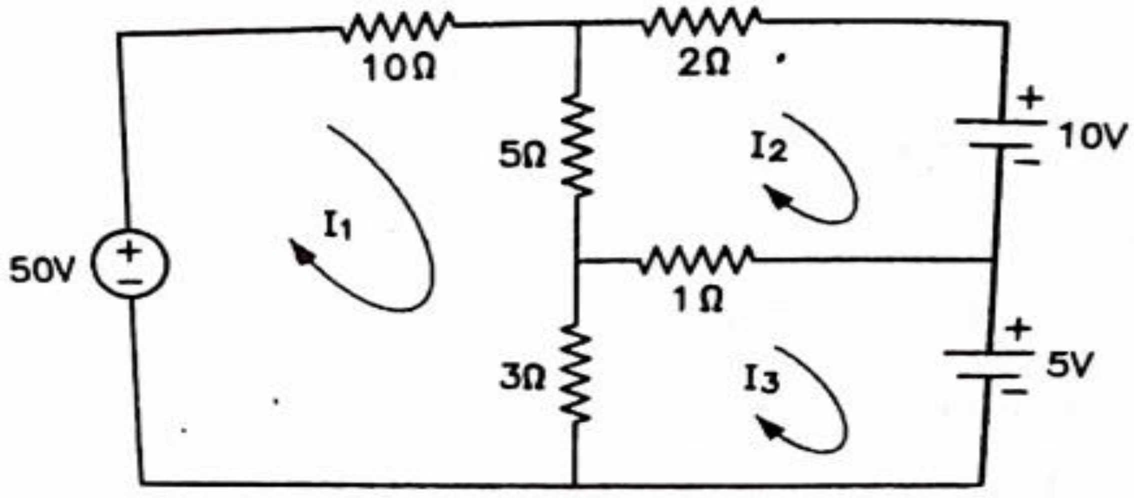
# Using Cramer's Rule to Solve a System of Three Equations

where

$$D = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{12} & a_{22} & a_{23} \\ a_{13} & a_{32} & a_{33} \end{vmatrix} \qquad D_1 = \begin{vmatrix} b_1 & a_{12} & a_{13} \\ b_2 & a_{22} & a_{23} \\ b_3 & a_{32} & a_{33} \end{vmatrix}$$

$$D_2 = \begin{vmatrix} a_{11} & b_1 & a_{13} \\ a_{12} & b_2 & a_{23} \\ a_{13} & b_3 & a_{33} \end{vmatrix} \qquad D_3 = \begin{vmatrix} a_{11} & a_{12} & b_1 \\ a_{12} & a_{22} & b_2 \\ a_{13} & a_{32} & b_3 \end{vmatrix}$$

1. Determine the mesh currents I1, I2 and I3 for the network shown below.




Applying KVL to the above circuit,

The mesh current equations are,

KVL for loop–1,

$$50 - 10\ I_1 - 5\ (I_1 - I_2) - 3\ (I_1 - I_3) = 0$$

$$\therefore \quad 50 = 18\ I_1 - 5\ I_2 - 3\ I_3$$

1

KVL for loop–2,

$$-2\,I_2 - 10 - 1\,(I_2 - I_3) - 5\,(I_2 - I_1) = 0$$

$$\therefore \quad -10 = -5\,I_1 + 8\,I_2 - I_3 \qquad 2$$

KVL for loop–3,

$$-5 - 3\,(I_3 - I_1) - 1\,(I_3 - I_2) = 0$$

$$\therefore \quad -5 = -3\,I_1 - I_2 + 4\,I_3 \qquad 3$$

From equation (1), (2) and (3)

$$\begin{bmatrix} 50 \\ -10 \\ -5 \end{bmatrix} = \begin{bmatrix} 18 & -5 & -3 \\ -5 & 8 & -1 \\ -3 & -1 & 4 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix}$$

$$\Delta R = \begin{vmatrix} 18 & -5 & -3 \\ -5 & 8 & -1 \\ -3 & -1 & 4 \end{vmatrix} = 356\ \Omega$$

$$\Delta R_1 = \begin{vmatrix} 50 & -5 & -3 \\ -10 & 8 & -1 \\ -5 & -1 & 4 \end{vmatrix} = 1175\ \Omega$$

$$\Delta R_2 = \begin{vmatrix} 18 & 50 & -3 \\ -5 & -10 & -1 \\ -3 & -5 & 4 \end{vmatrix} = 355\ \Omega$$

$$\Delta R_3 = \begin{vmatrix} 18 & -5 & 50 \\ -5 & 8 & -10 \\ -3 & -1 & -5 \end{vmatrix} = 525\ \Omega$$

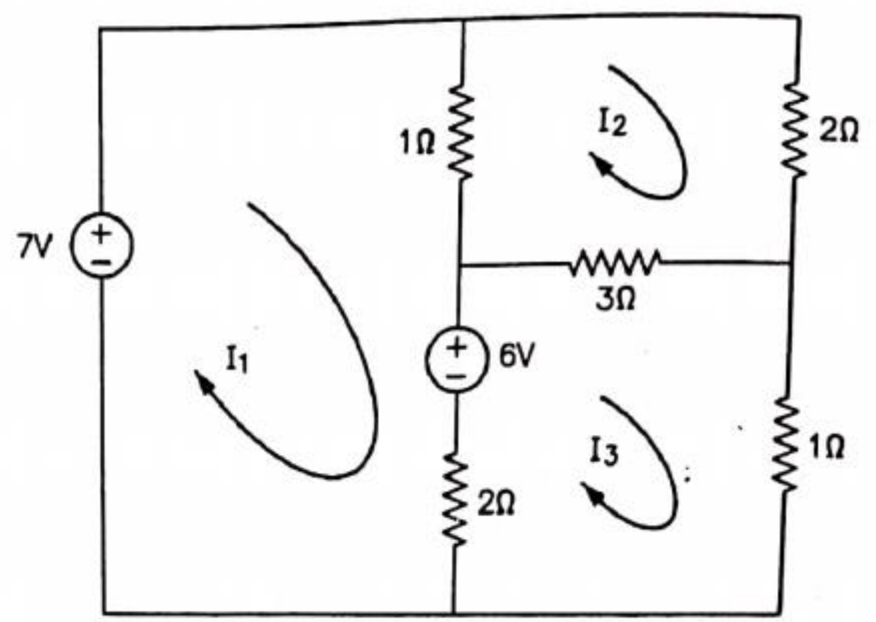
Using cramer's rule,

$$I_1 = \frac{\Delta R_1}{\Delta R} = \frac{1175}{356} = \boxed{3.30 \text{ amp.}}$$

$$I_2 = \frac{\Delta R_2}{\Delta R} = \frac{355}{356} = \boxed{0.99 \text{ amp.}}$$

$$I_3 = \frac{\Delta R_3}{\Delta R} = \frac{525}{356} = \boxed{1.47 \text{ amp.}}$$

2. Determine the mesh currents I1, I2 and I3 for the network shown below.




Writing KVL equations for the above circuit, the mesh current equations are.

KVL for loop–1,

$$7 - 1\,(I_1 - I_2) - 6 - 2\,(I_1 - I_3) = 0$$

$$\therefore \quad 1 = 3\,I_1 - I_2 - 2I_3$$

KVL for loop–2,

$$-2\,I_2 - 3\,(I_2 - I_3) - 1\,(I_2 - I_1) = 0$$

$$\therefore \quad 0 = -\,I_1 + 6\,I_2 - 3\,I_3$$

2

KVL for loop–3,

$$-\,I_3 - 2\,(I_3 - I_1) + 6 - 3\,(I_3 - I_2) = 0$$

$$\therefore \quad 6 = -\,2\,I_1 - 3\,I_2 + 6\,I_3$$

3

From equation (1), (2) and (3),

$$\begin{bmatrix} 1 \\ 0 \\ 6 \end{bmatrix} \begin{bmatrix} 3 & -1 & -2 \\ -1 & 6 & -3 \\ -2 & -3 & 6 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\Delta R = \begin{vmatrix} 3 & -1 & -2 \\ -1 & 6 & -3 \\ -2 & -3 & 6 \end{vmatrix} = 39\ \Omega$$

$$\Delta R_1 = \begin{vmatrix} 1 & -1 & -2 \\ 0 & 6 & -3 \\ 6 & -3 & 6 \end{vmatrix} = 117\ \Omega$$

$$\Delta R_2 = \begin{vmatrix} 3 & 1 & -2 \\ -1 & 0 & -3 \\ -2 & 6 & 6 \end{vmatrix} = 78\ \Omega$$

$$\Delta R_3 = \begin{vmatrix} 3 & -1 & 1 \\ -1 & 6 & 0 \\ -2 & -3 & 6 \end{vmatrix} = 117\ \Omega$$

Using cramer's rule,

$$I_1 = \frac{\Delta R_1}{\Delta R} = \frac{117}{39} = \boxed{3\ \text{amp.}}$$

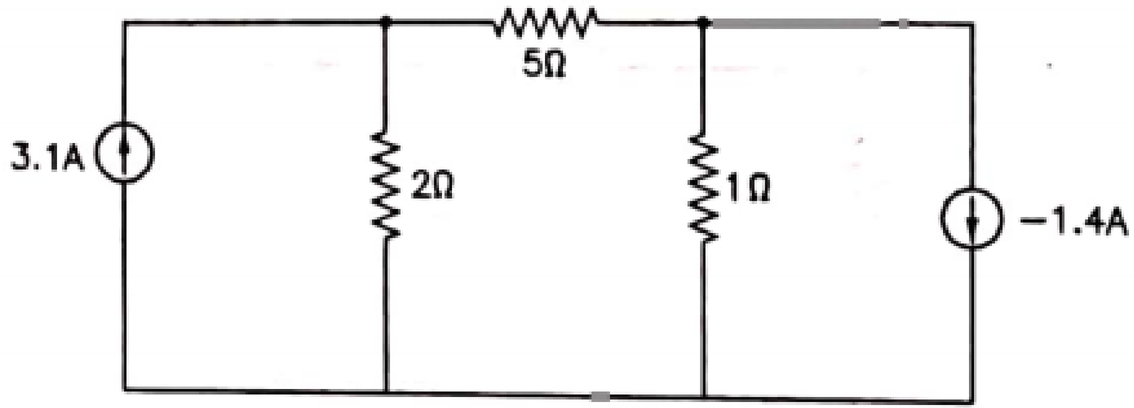
$$I_2 = \frac{\Delta R_2}{\Delta R} = \frac{78}{39} = \boxed{2\ \text{amp.}}$$

$$I_3 = \frac{\Delta R_3}{\Delta R} = \frac{117}{39} = \boxed{3\ \text{amp.}}$$

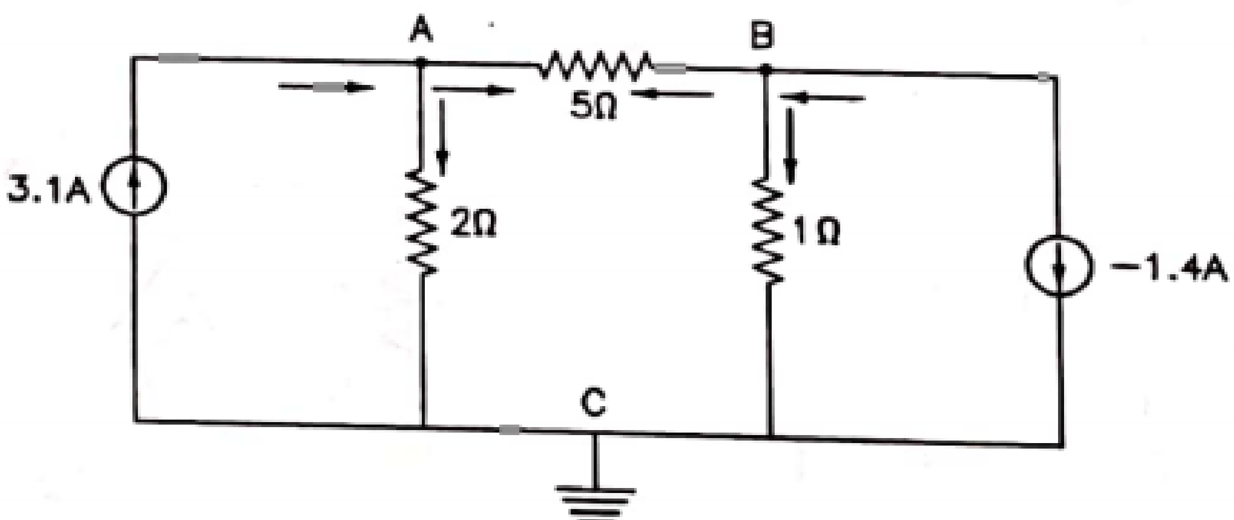
# Nodal Analysis

- Nodal analysis is a technique used to analyze circuits with more than one voltage source.
- Based on KCL, it is used to determine the voltages of the nodes in a circuit.
- Once you determine the node voltages, it is possible to find all branch voltages, currents and the power supplied or absorbed by each circuit element.

3. Use nodal analysis to find voltage across 5Ω resistor, for the network shown below.




**Step-1 :** Identify the no. of nodes in the given circuit.



**Step-2 :** Apply KCL at each node in the circuit except reference node.

Let us assume potential at node A is $V_A$ and potential at node B is $V_B$ as shown.

**Applying KCL at node-A,**

$$3.1 = \frac{V_A}{2} + \frac{V_A - V_B}{5}$$

$$\therefore \quad 0.7\ V_A - 0.2\ V_B = 3.1 \quad \ldots\ldots. (1)$$

**Applying KCL at node-B**

$$\frac{V_B}{1} + \frac{V_B - V_A}{5} = 1.4$$

$$-0.2\ V_A + 1.2\ V_B = 1.4 \quad \ldots\ldots. (2)$$

From equations (1) and (2),

$$\begin{bmatrix} 0.7 & -0.2 \\ -0.2 & 1.2 \end{bmatrix} \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 3.1 \\ 1.4 \end{bmatrix}$$

$$\Delta G = \begin{vmatrix} 0.7 & -0.2 \\ -0.2 & 1.2 \end{vmatrix} = 0.8 \qquad \Delta G_1 = \begin{vmatrix} 3.1 & -0.2 \\ 1.4 & 1.2 \end{vmatrix} = 4 \qquad \Delta G_2 \begin{vmatrix} 0.7 & 3.1 \\ -0.2 & 1.4 \end{vmatrix} = 1.6$$

Using cramer's rule,

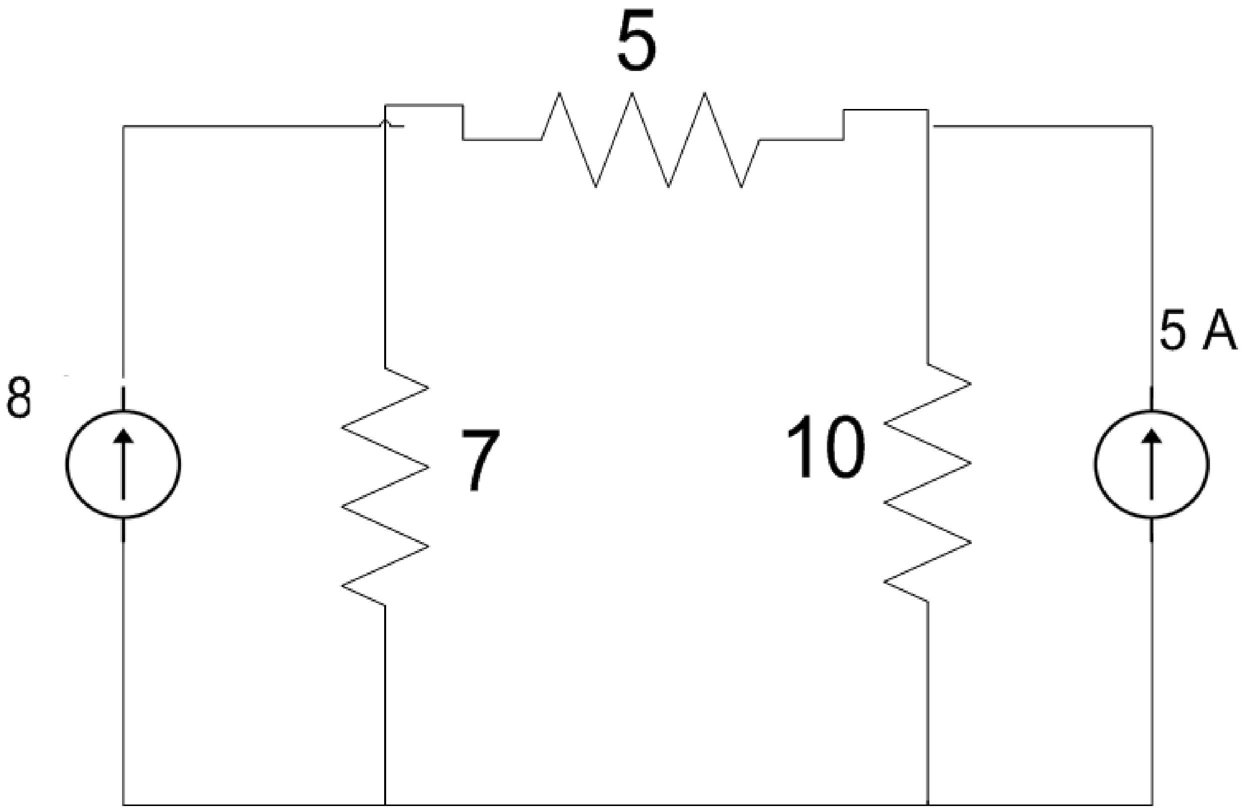
$$\therefore \quad V_A = \frac{\Delta G_1}{\Delta G} = \frac{4}{0.8} = 5 \text{ volts} \qquad V_B = \frac{\Delta G_2}{\Delta G} = \frac{1.6}{0.8} = 2 \text{ volts}$$

Hence, the voltage across 5Ω resistor is

$$V_5 = V_A - V_B$$

$$= \boxed{3 \text{ volt}}$$

- Use nodal analysis to find voltage across 5Ω resistor, for the network shown below.




**VA=54.09 V** **VB=52.27 V** **V5=1.37 V**

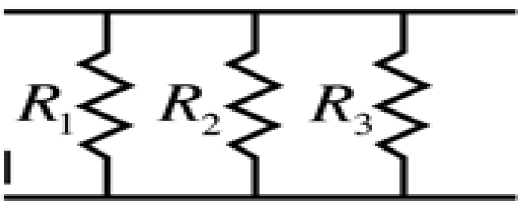
# Series- Parallel Circuits


Series

$$\boxed{R_{equivalent} = R_1 + R_2 + R_3 + \ldots}$$

$$R_{equivalent} = \frac{V}{I} = \frac{V_1 + V_2 + V_3 + \ldots}{I} = \frac{V_1}{I_1} + \frac{V_2}{I_2} + \frac{V_3}{I_3} + \ldots = R_1 + R_2 + R_3 + \ldots$$

Series key idea: The current is the same in each resistor by the current law.




Parallel

$$\boxed{\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$$

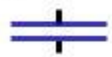
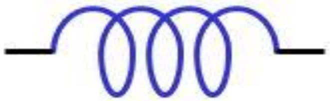
Parallel:

$$\frac{V}{R_{equivalent}} = I = I_1 + I_2 + I_3 + \ldots = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \ldots$$

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

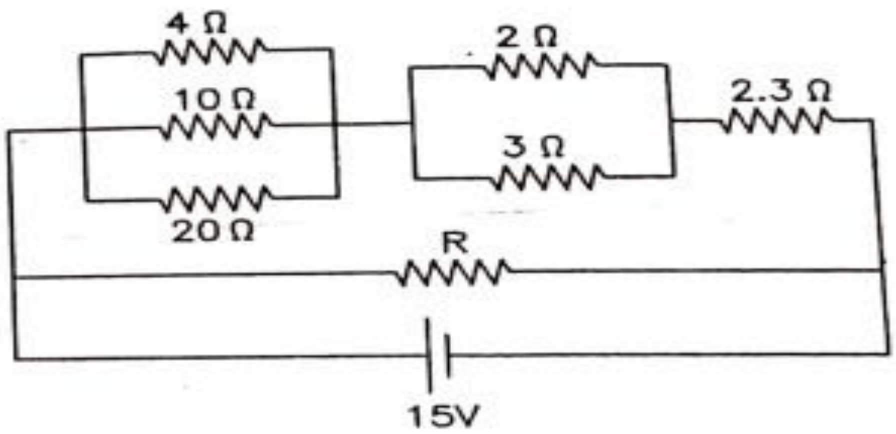
Parallel key idea: The voltage is the same across each resistor by the voltage law.

# Parallel and Series - Formulas

| | Capacitor  | Resistor  | Inductor*  |
|---|---|---|---|
| Series | $\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}$ | $R=R_1+R_2$ | $L=L_1+L_2$ |
| Parallel | $C=C_1+C_2$ | $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}$ | $\frac{1}{L}=\frac{1}{L_1}+\frac{1}{L_2}$ |
| Fundamental Formula | $\Delta V=\frac{Q}{C}$ | $\Delta V=IR$ | $\mathrm{E}_L=-L\frac{dI}{dt}$ |

* To be defined in a later chapter

4. Determine the value of R so that the current supplied by the battery is 5 A.




The equivalent of this combination is given by

$$\frac{1}{R_1} = \frac{1}{4} + \frac{1}{10} + \frac{1}{20} = \frac{8}{20}$$

$$\therefore \; R_1 = \frac{20}{8} = 2.5\ \Omega$$

Similarly Resistances 2 Ω and 3 Ω are in parallel. Hence their equivalent resistance is given by

$$R_2 = \frac{2 \times 3}{2+3} = 1.2\,\Omega$$

series combination = 2.5 + 1.2 + 2.3 = 6 Ω.

This resistance of 6 Ω is in parallel with unknown resistance $R$. So total resistance of the circuit $= 6 \| R = \dfrac{6R}{R+6}\,\Omega$ ... (i)

Again total current = 5 A

and battery voltage = 15 V

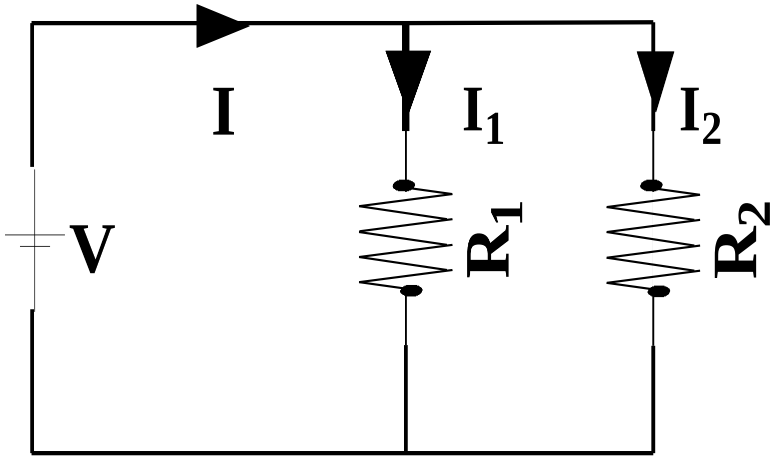
$\therefore$ Total resistance $= \dfrac{15}{5} = 3\,\Omega$ ... (ii)

Equating equations (i) and (ii)

$$\frac{6R}{R+6} = 3$$

$$\boxed{R = 6\,\Omega}$$

# Current Division in Parallel Circuits

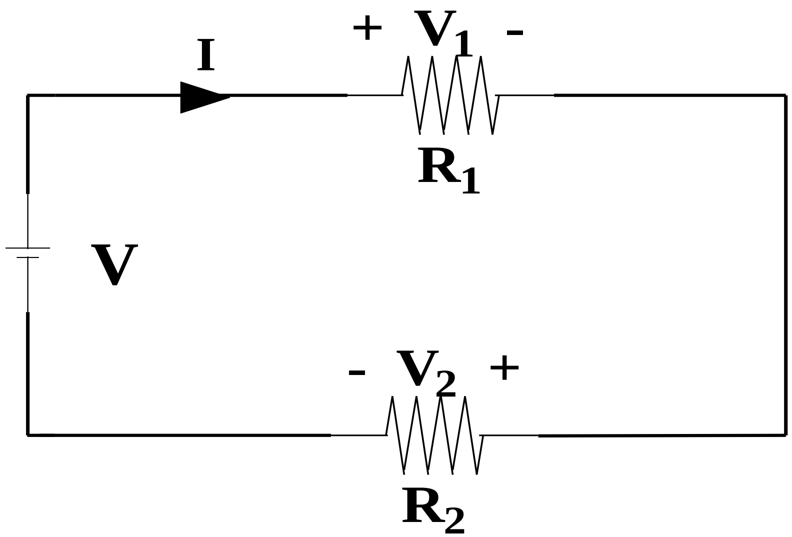



$$I = I_1 + I_2$$

$$I_1 = I\frac{R_2}{R_1 + R_2}$$

$$I_2 = I\frac{R_1}{R_1 + R_2}$$

# Voltage Division in Series Circuits

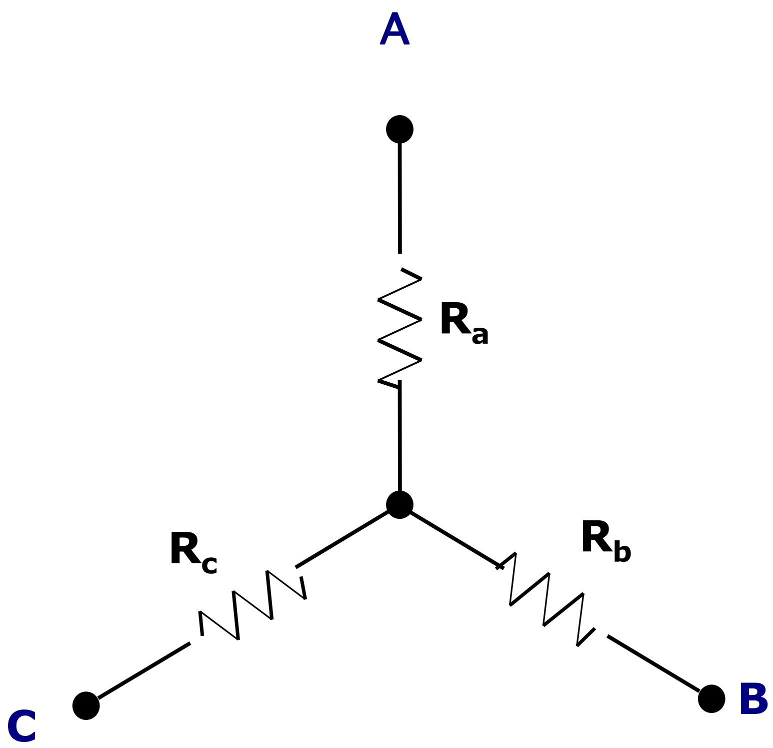



$$V = V_1 + V_2$$

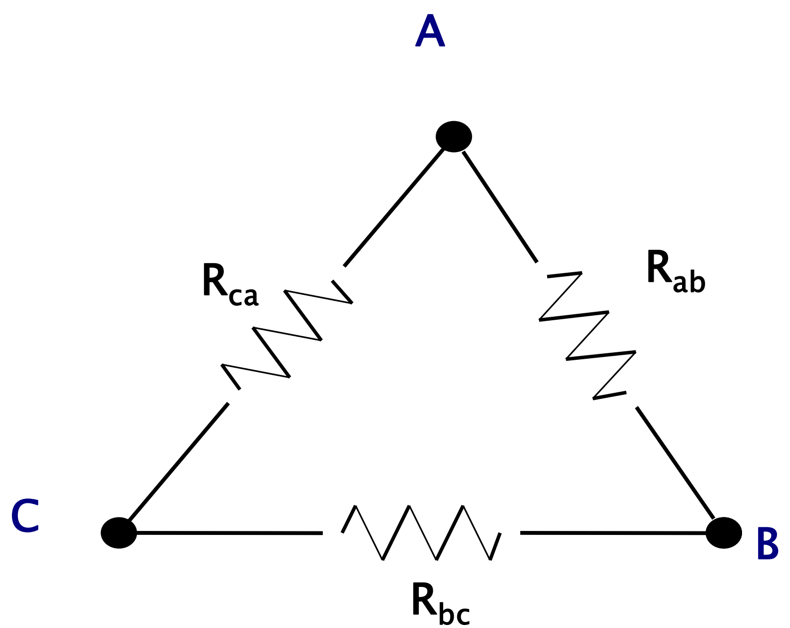
$$V_1 = V\frac{R_1}{R_1 + R_2}$$

$$V_2 = V\frac{R_2}{R_1 + R_2}$$

# Star- Delta Transformation

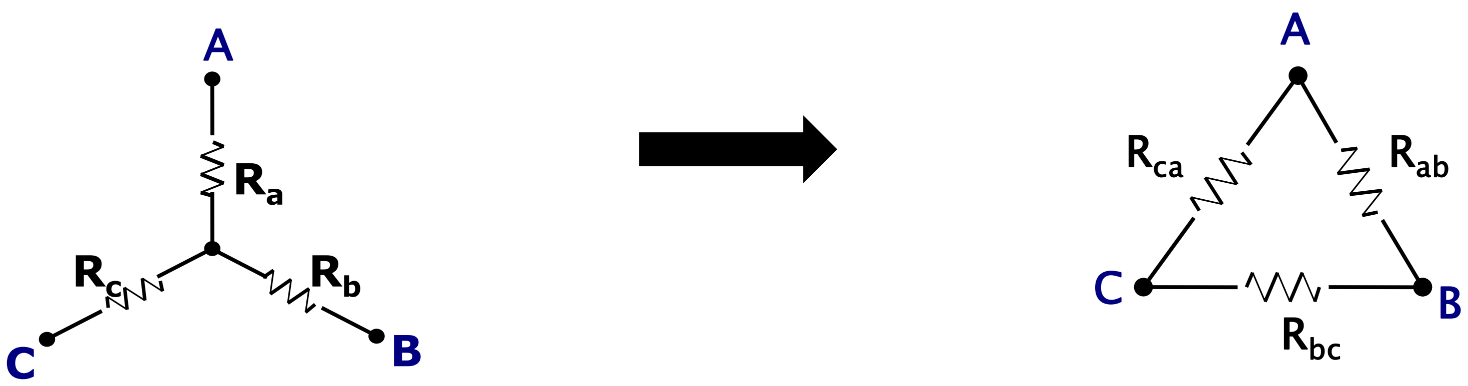



Star Connection




Delta Connection

# Star to Delta Transformation:

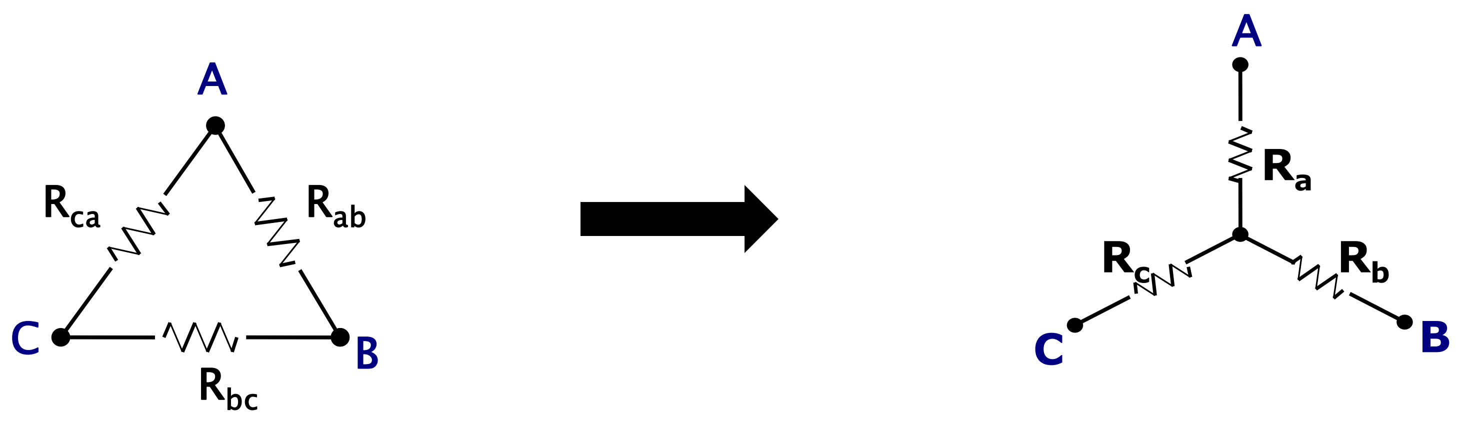



$$R_{ab} = R_a + R_b + \frac{R_a R_b}{R_c}$$

$$R_{bc} = R_b + R_c + \frac{R_b R_c}{R_a}$$

$$R_{ca} = R_c + R_a + \frac{R_c R_a}{R_b}$$

# Star to Delta Transformation:

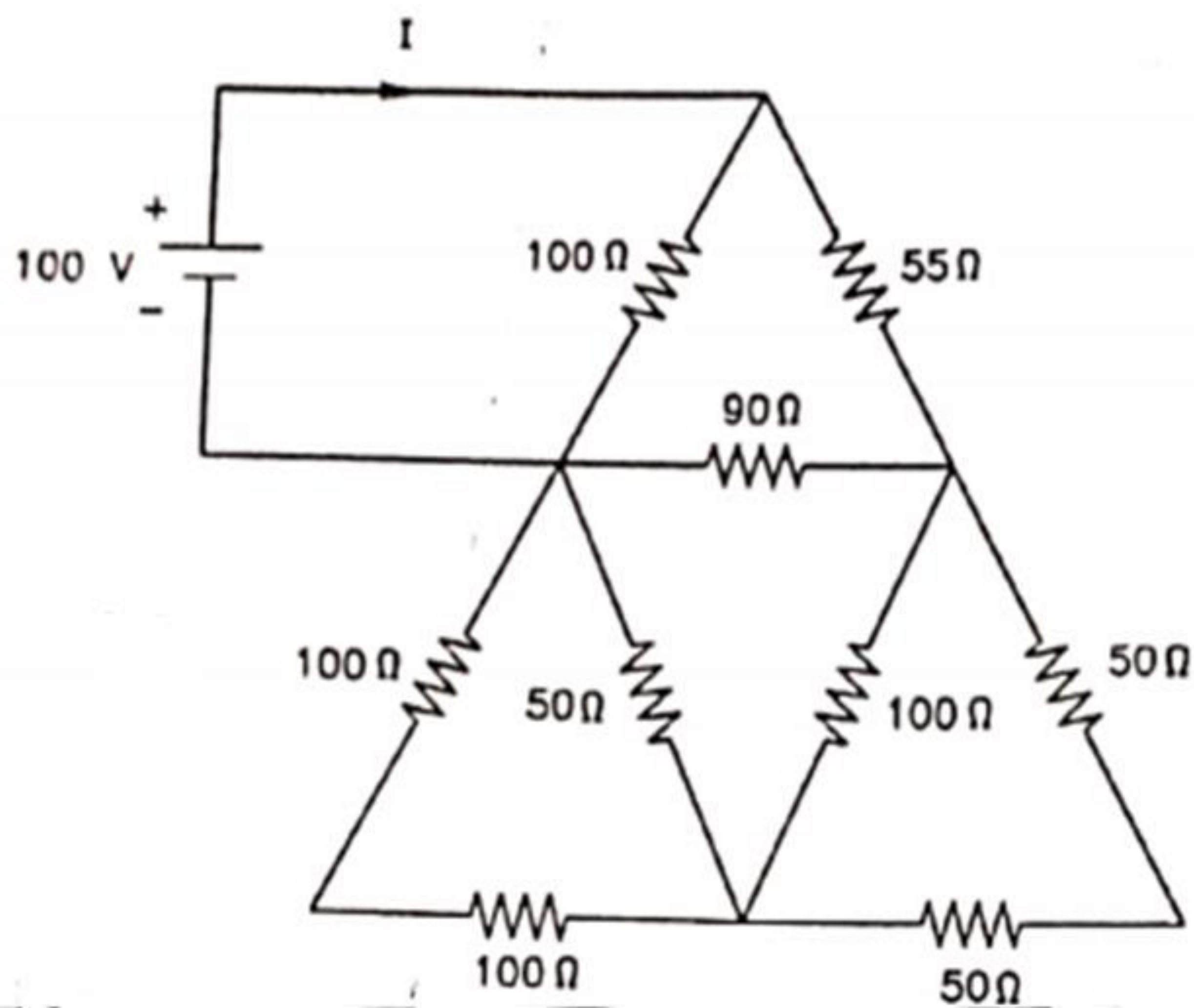


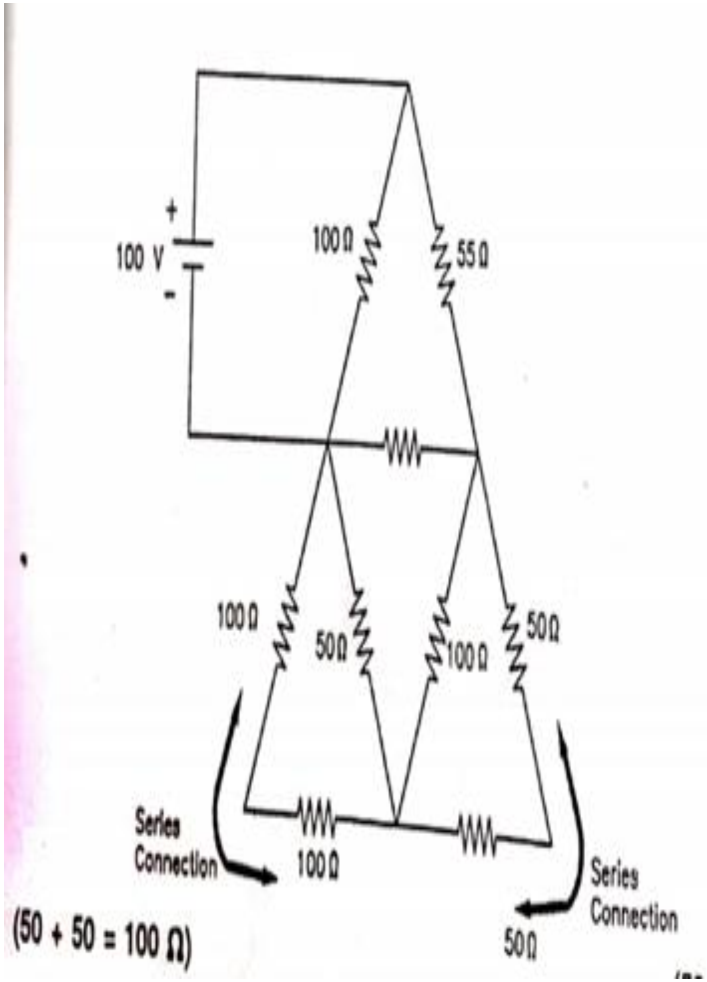

$$R_a = \frac{R_{ab}\,R_{ca}}{R_{ab} + R_{bc} + R_{ca}}$$

$$R_b = \frac{R_{bc}\,R_{ab}}{R_{ab} + R_{bc} + R_{ca}}$$

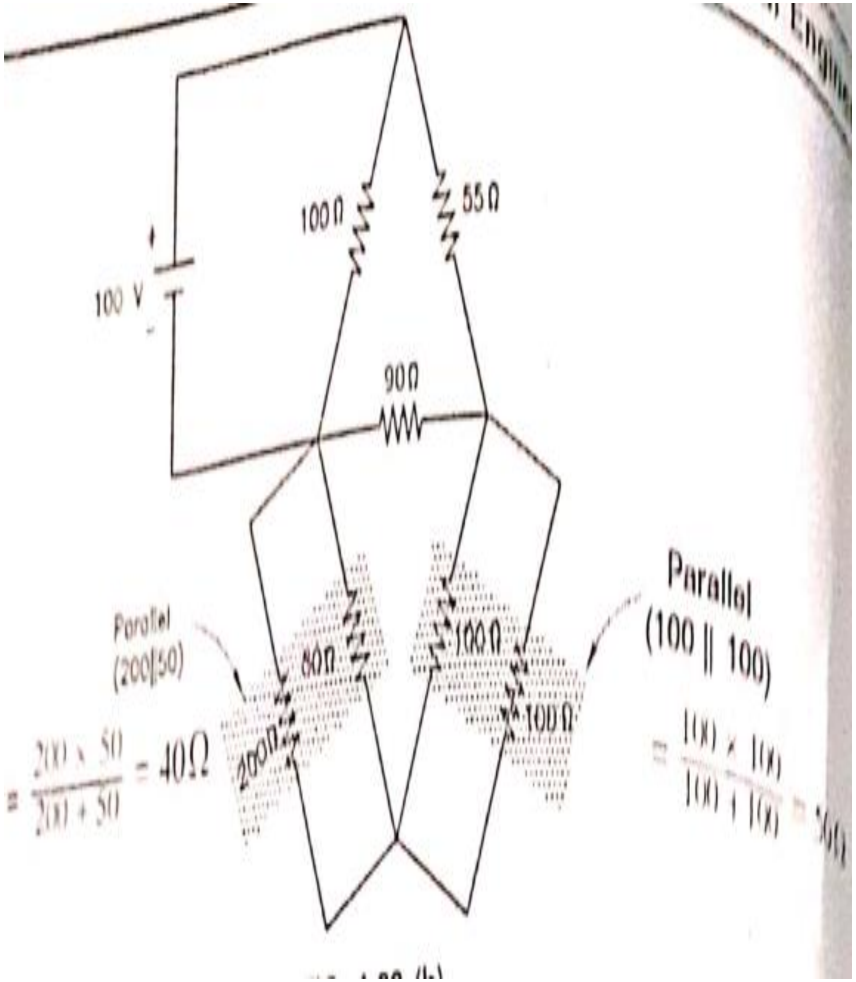
$$R_c = \frac{R_{ca}\,R_{bc}}{R_{ab} + R_{bc} + R_{ca}}$$

1. For this circuit shown in fig. below calculate the current taken by circuit.

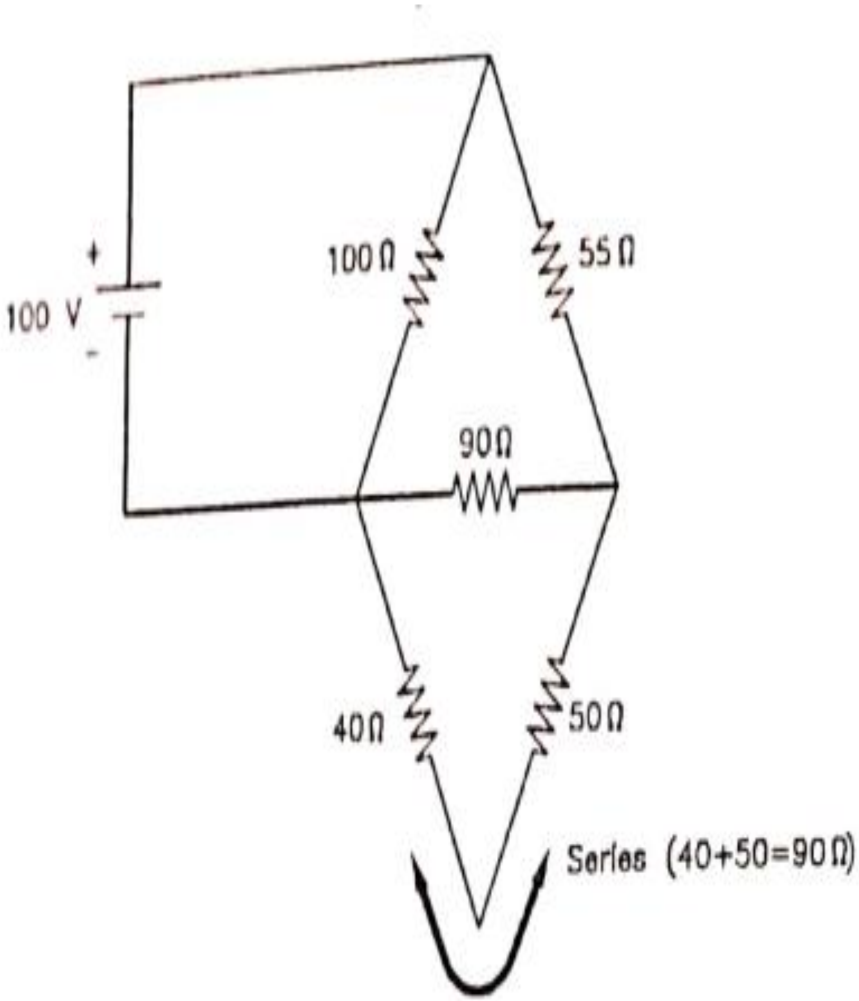




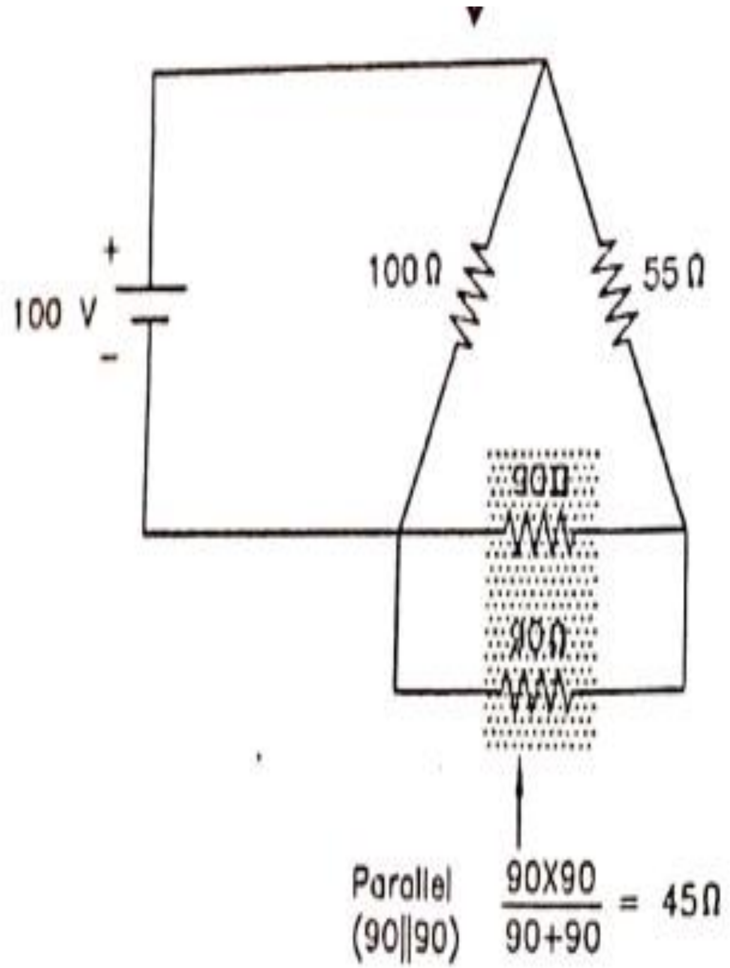
100 V
100 Ω
55 Ω
100 Ω
50 Ω
100 Ω
50 Ω
Series Connection
100 Ω
Series Connection
50 Ω
(50 + 50 = 100 Ω)

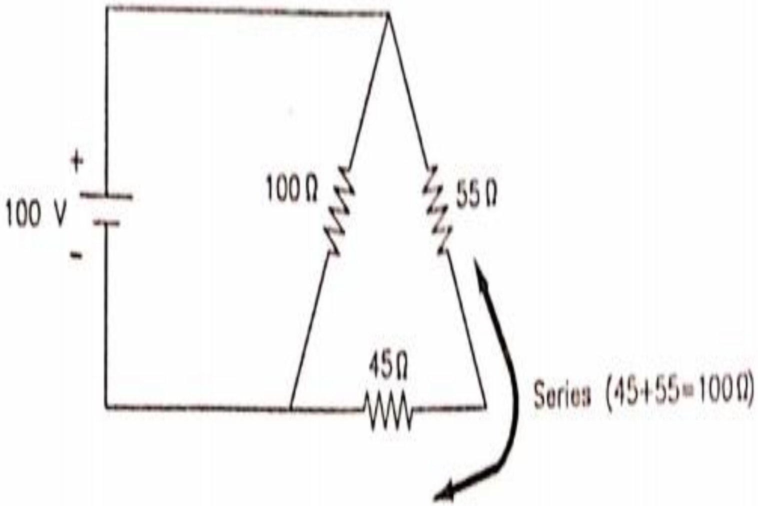
100 V
100 Ω
55 Ω
90 Ω
80 Ω
100 Ω
100 Ω
200 Ω
Parallel (200||50)
Parallel (100 || 100)

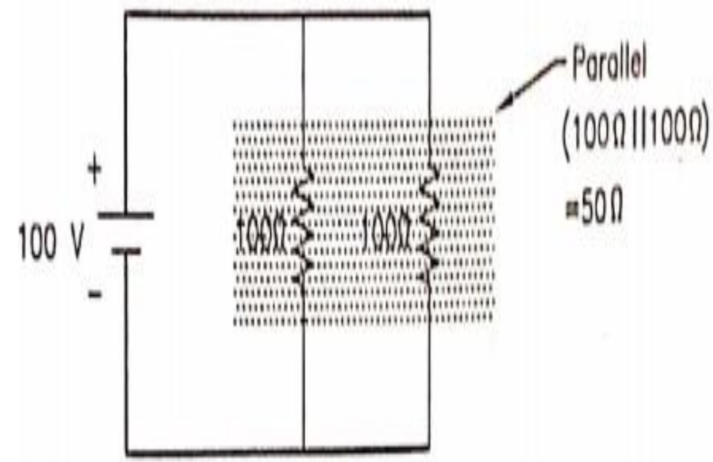


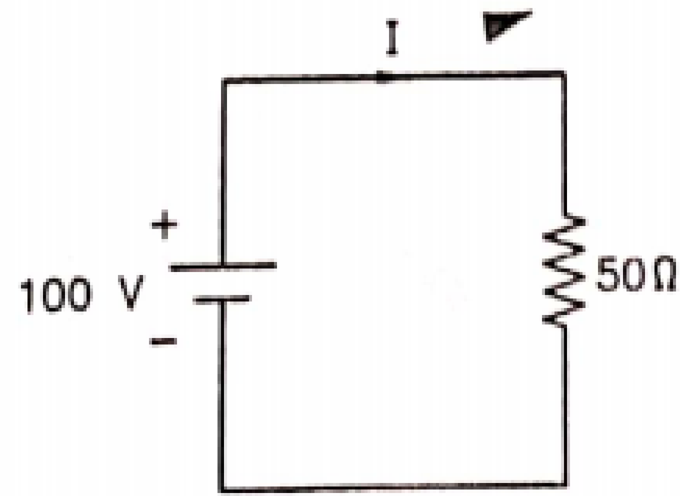
100 V
+
-
100 Ω
55 Ω
90 Ω
40 Ω
50 Ω
Series (40+50=90 Ω)

100 V
+
-
100 Ω
55 Ω
90 Ω
90 Ω
Parallel (90||90)
$\frac{90X90}{90+90} = 45\Omega$



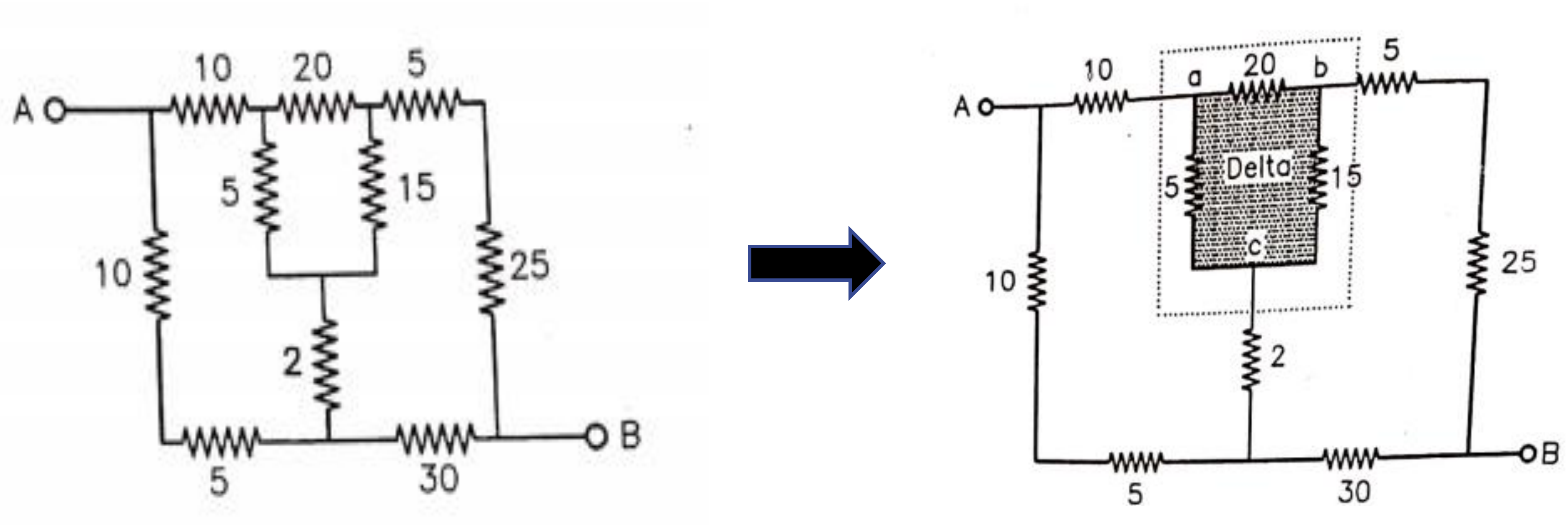



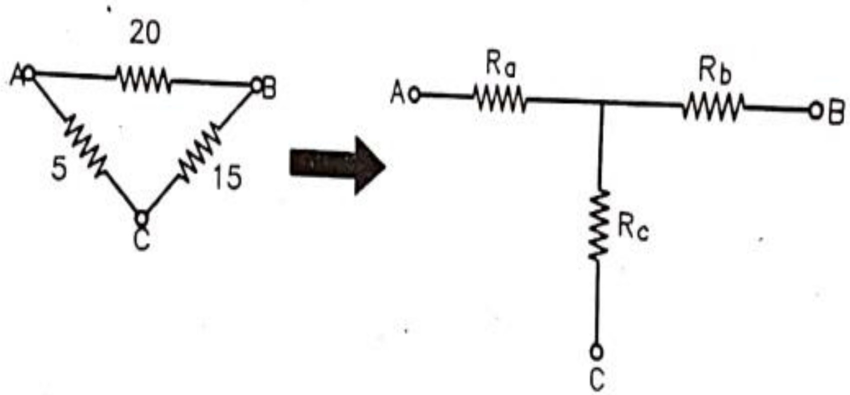




Current taken by circuit

$$I = \frac{100}{50} = \boxed{2\ \text{A}}$$

3. Using star- delta transformation , determine the resistance between the terminal A & B in the given circuit.

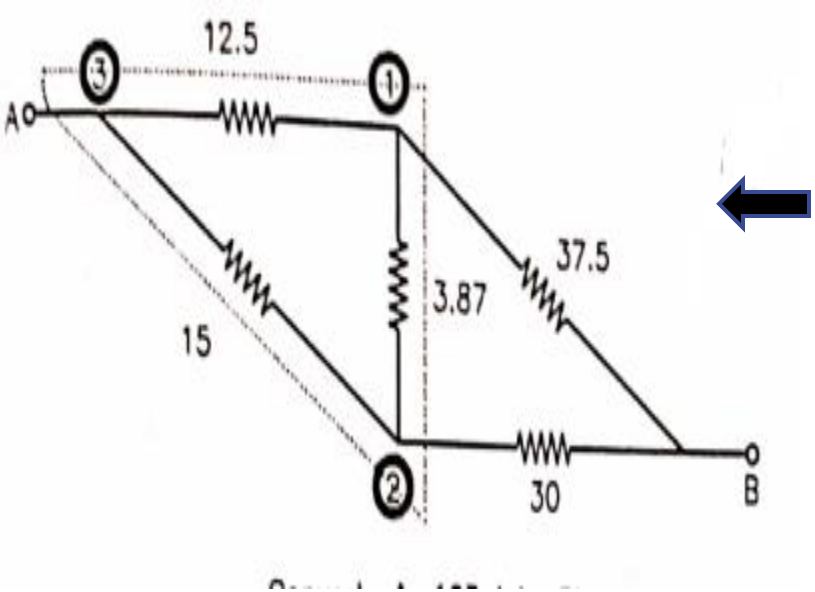


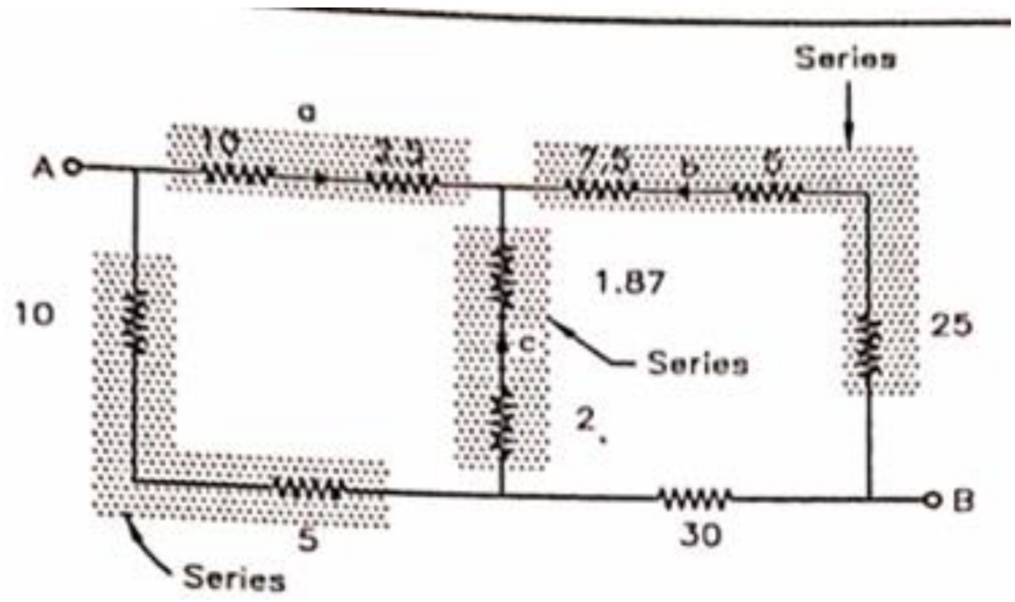



$$R_a = \frac{R_{ab} \times R_{ac}}{R_{ab} + R_{bc} + R_{ac}} = \frac{20 \times 5}{20+15+5} = \frac{100}{40} = 2.5\ \Omega$$

$$R_b = \frac{R_{ab} \times R_{bc}}{R_{ab} + R_{bc} + R_{ac}} = \frac{20 \times 15}{20+15+5} = \frac{300}{40} = 7.5\ \Omega$$

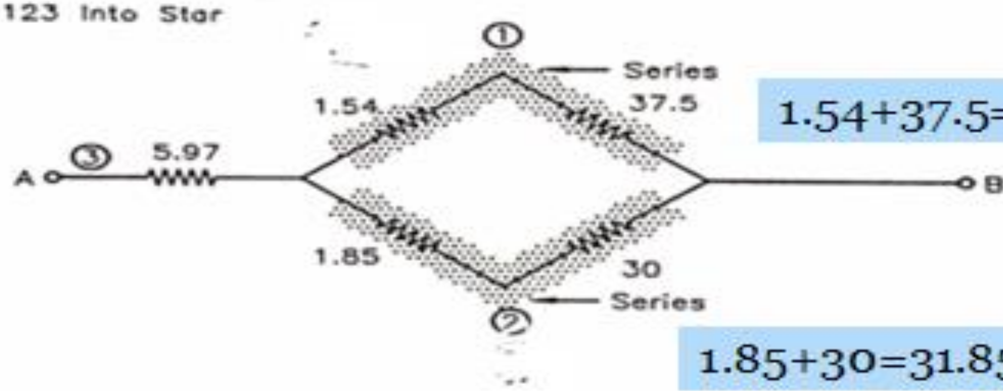
$$R_c = \frac{R_{ab} \times R_{bc}}{R_{ab} + R_{bc} + R_{ac}} = \frac{15 \times 15}{20+15+5} = \frac{75}{40} = 1.87\ \Omega$$



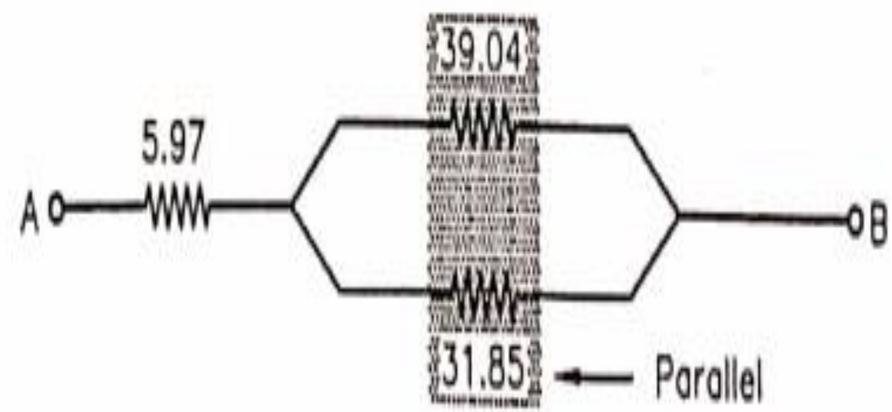
Convert Δ 123 Into Star

Convert Δ123 into Star :




$1.54+37.5=39.04\Omega$

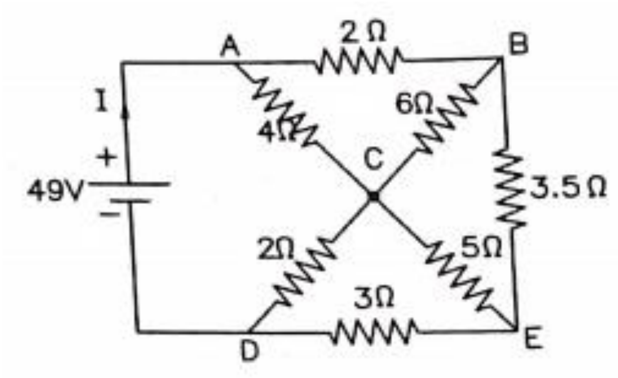
$1.85+30=31.85\Omega$

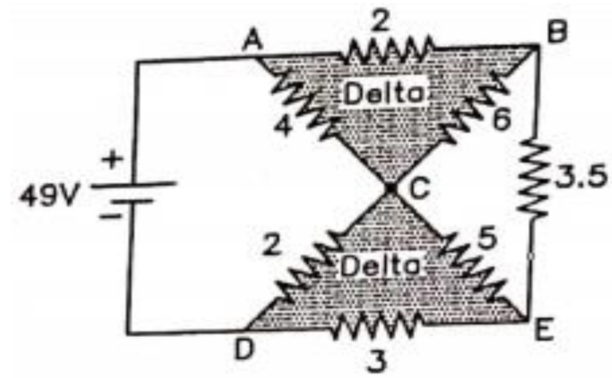


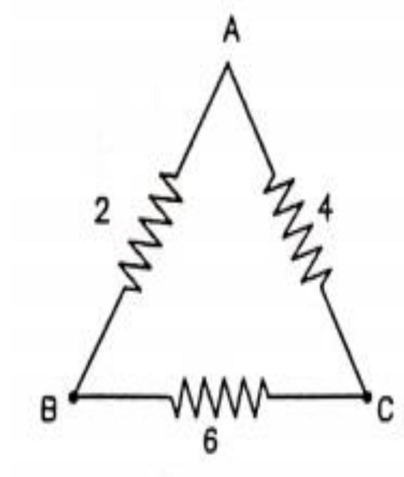


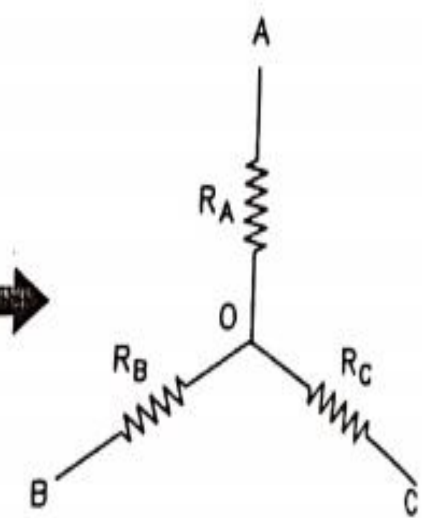
$$R_{AB} = 5.97 + 17.54 = \boxed{23.51\ \Omega}$$

4. Calculate the current supplied by the battery in the network of fig shown below.



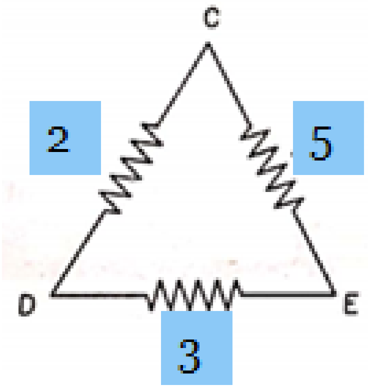



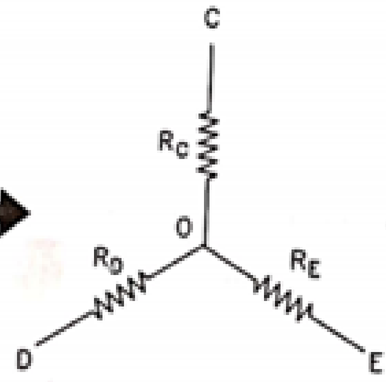




$$R_A = \frac{2 \times 4}{2+4+6} = \frac{2}{3}\ \Omega$$

$$R_B = \frac{2 \times 6}{2+4+6} = 1\ \Omega$$

$$R_C = \frac{6 \times 4}{6+4+2} = 2\ \Omega$$

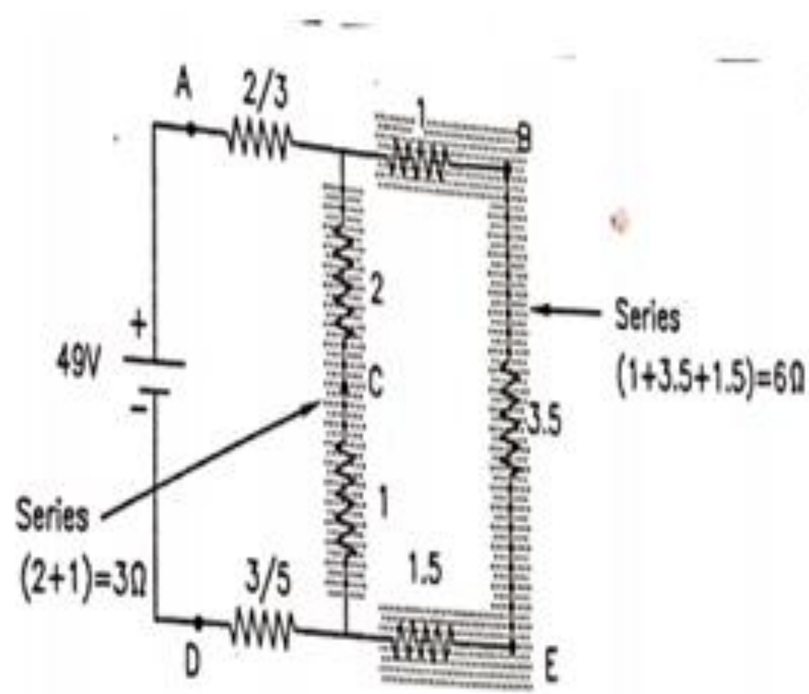


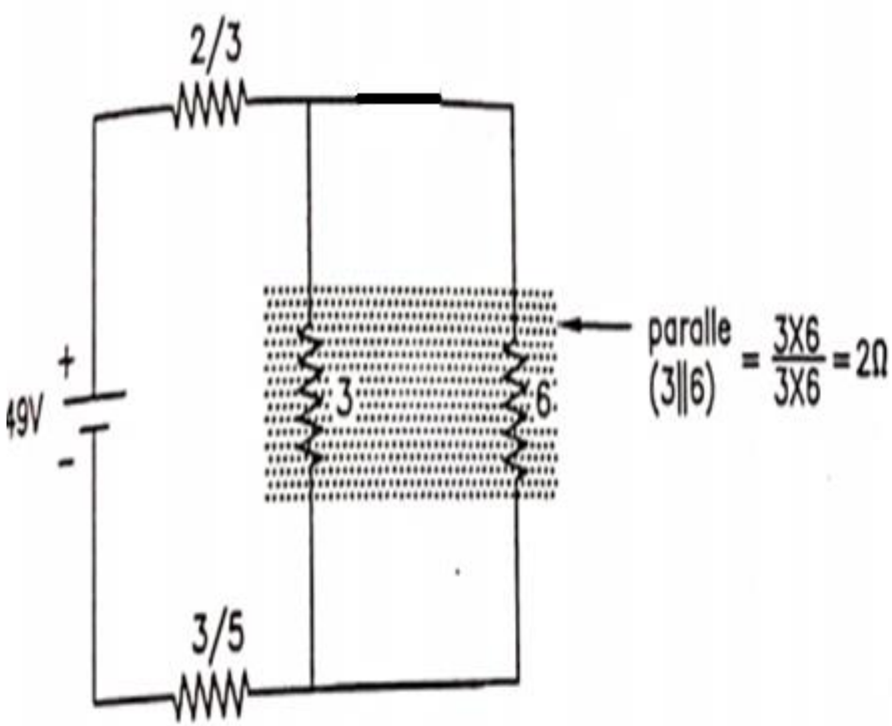



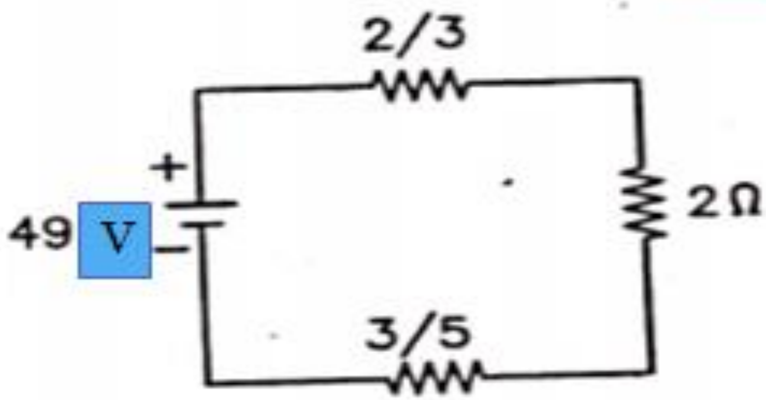

$$R_C = \frac{2 \times 5}{2+5+3} = 1\,\Omega$$

$$R_D = \frac{2 \times 3}{2+5+3} = \frac{3}{5}\,\Omega$$

$$R_E = \frac{3 \times 5}{2+5+3} = 1.5\,\Omega$$



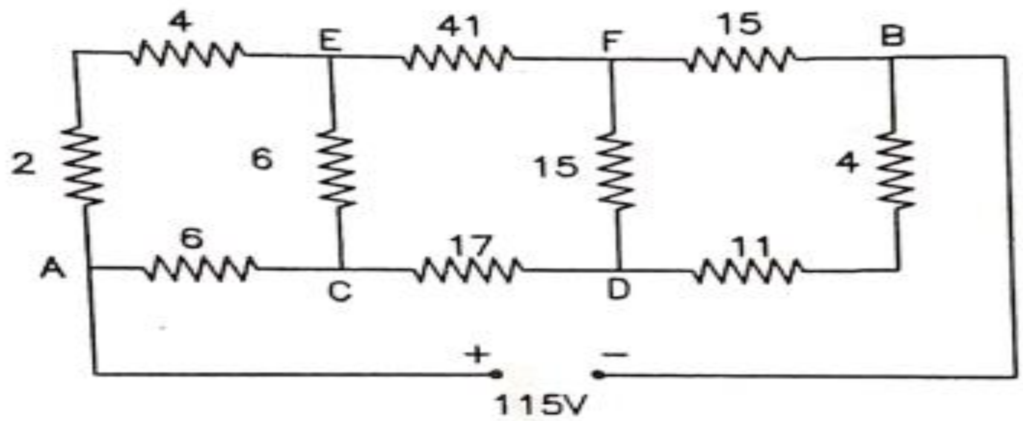


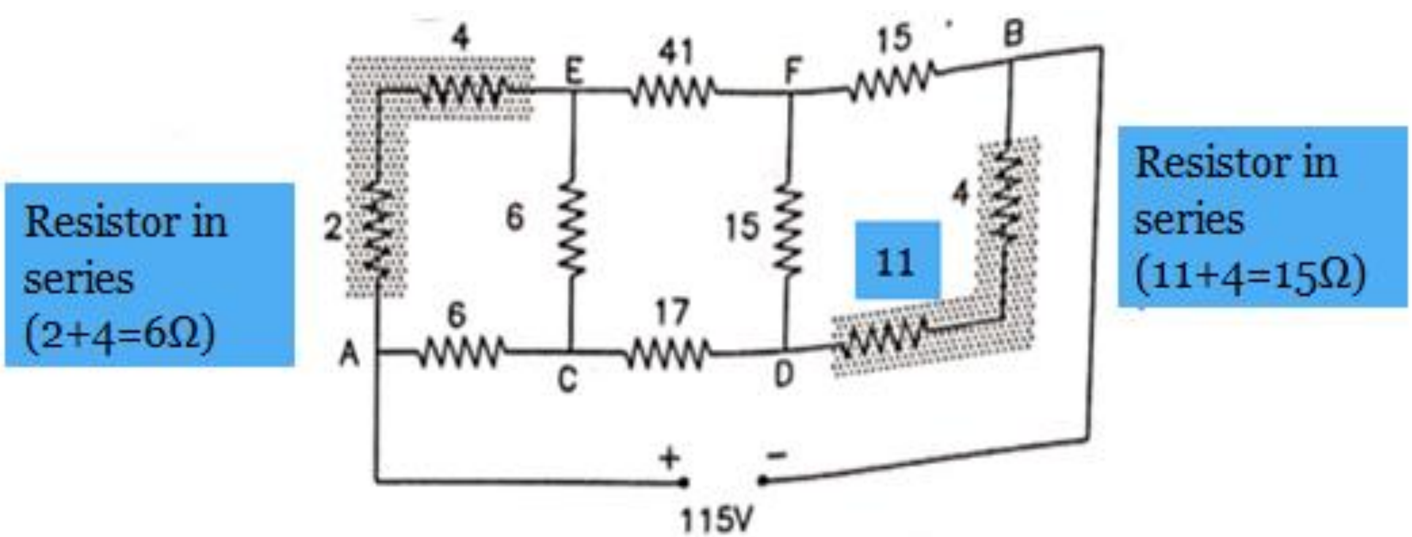

Now resistances $\frac{2}{3}\Omega$, $2\Omega$ an $\frac{3}{5}$ are in series, so total resistance of the circuit is given by,

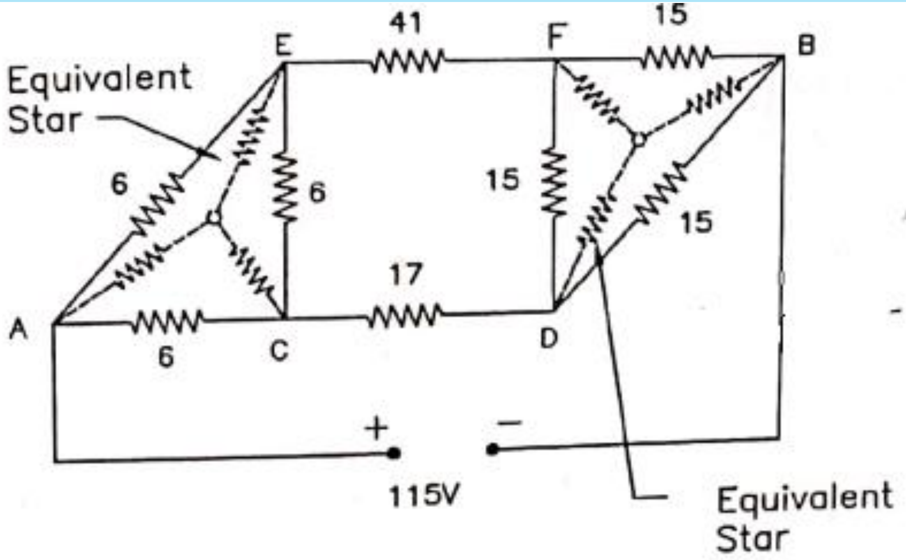
$$R_{eq} = \frac{2}{3} + 2 + \frac{3}{5} = \frac{49}{15}\ \Omega$$

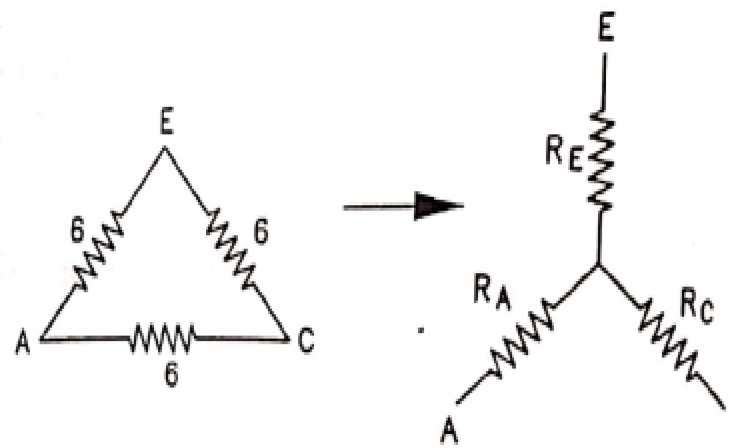
$$\therefore \text{ Current supplied by the battery} = \frac{49}{49/15} = \boxed{15\text{ A}}$$

5. Determine the current in the 17 Ω resistor in the network shown below.



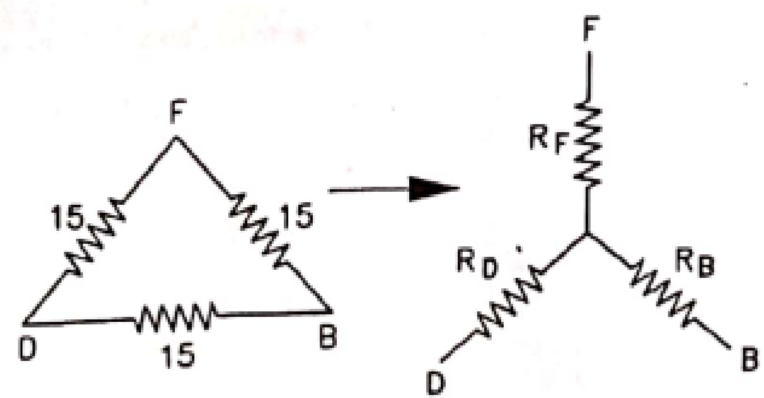





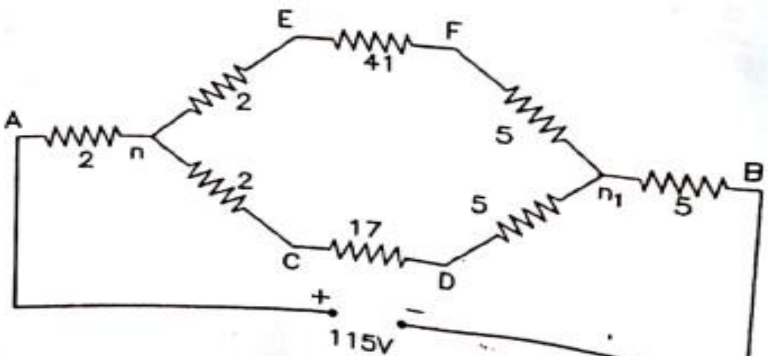




Applying Δ/Y transformation,

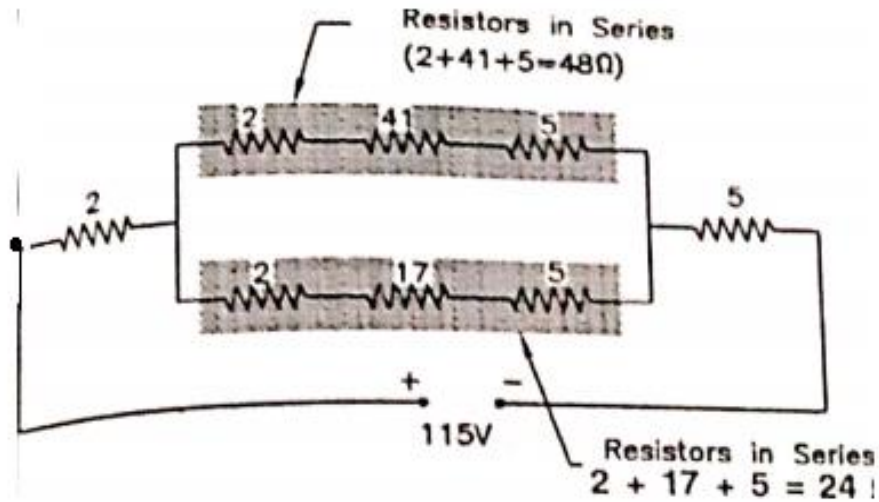
$$R_E = R_A = R_C = \frac{6 \times 6}{6+6+6} = 2\ \Omega$$

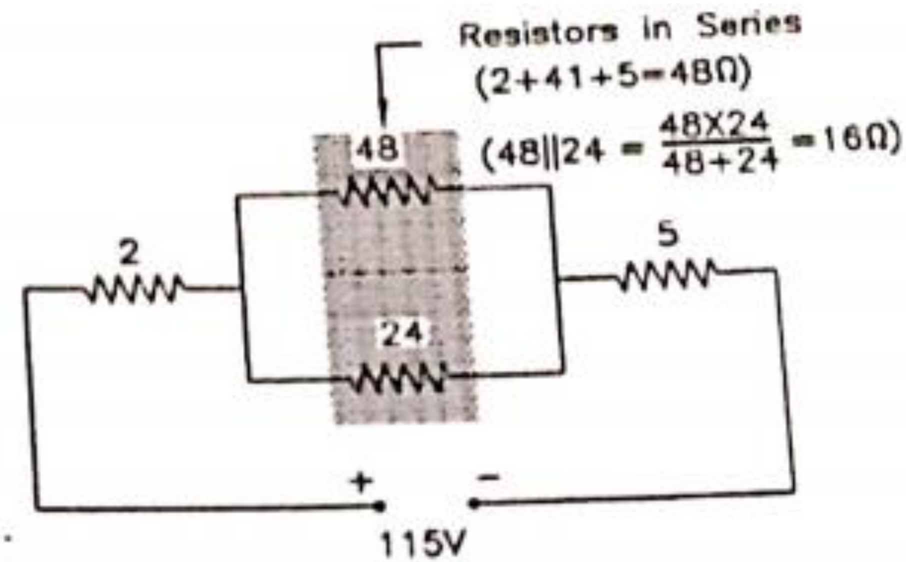


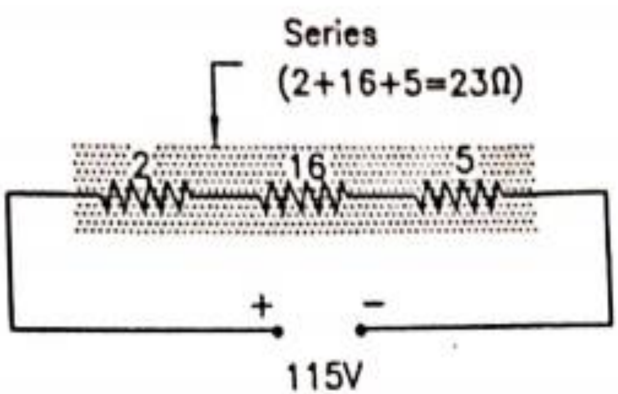

$$R_D = R_F = R_B = \frac{15 \times 15}{15+15+15} = 5\ \Omega$$


E
F
41
2
5
A
2
n
2
B
5
17
5
$n_1$
5
C
D
+
–
115V

(d)


Resistors in Series
(2+41+5=48Ω)
2
41
5
2
5
2
17
5
+
–
115V
Resistors in Series
2 + 17 + 5 = 24


Resistors in Series
(2+41+5=48Ω)
48
$(48||24 = \frac{48 \times 24}{48+24} = 16\Omega)$
2
5
24
+
–
115V


Series
(2+16+5=23Ω)
2
16
5
+
–
115V

$$\boxed{\text{The current taken by the circuit} = \frac{115}{23} = 5\ \text{A}}$$

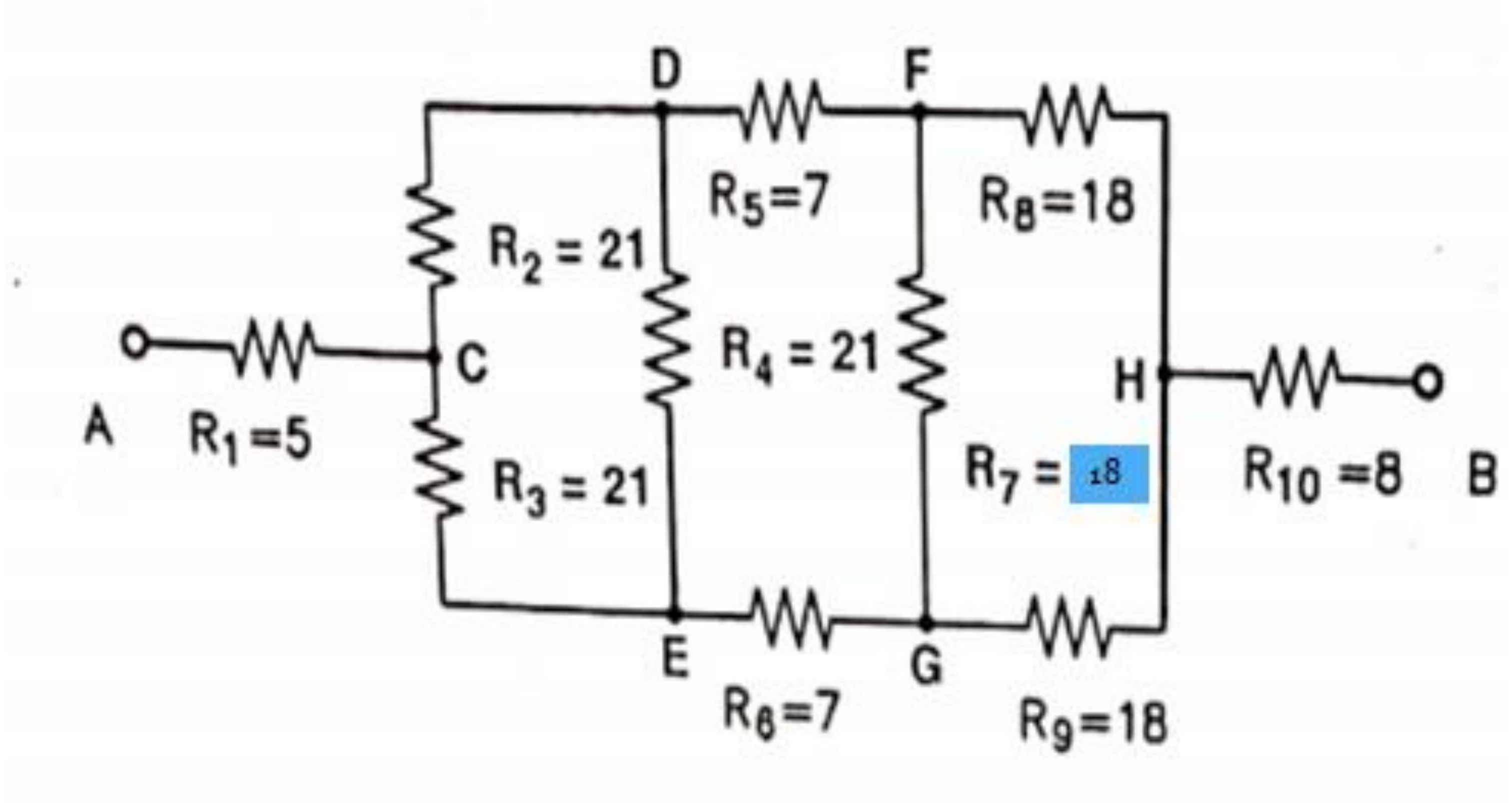
The current through 17 Ω resistor is the same as the current in 24 Ω resistor

The circuit current divides in 24 Ω and 48 Ω. So current in 17 Ω resistor is given by,

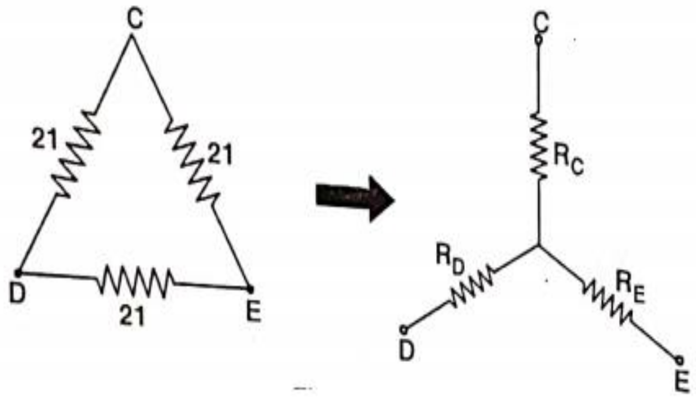
$$I = 5 \times \frac{48}{48 + 24}$$

$$\boxed{I = 5 \times \frac{48}{48 + 24} = \frac{10}{3}\ \text{A}}$$

6. Find the resistance between terminals A and B as shown in fig below.

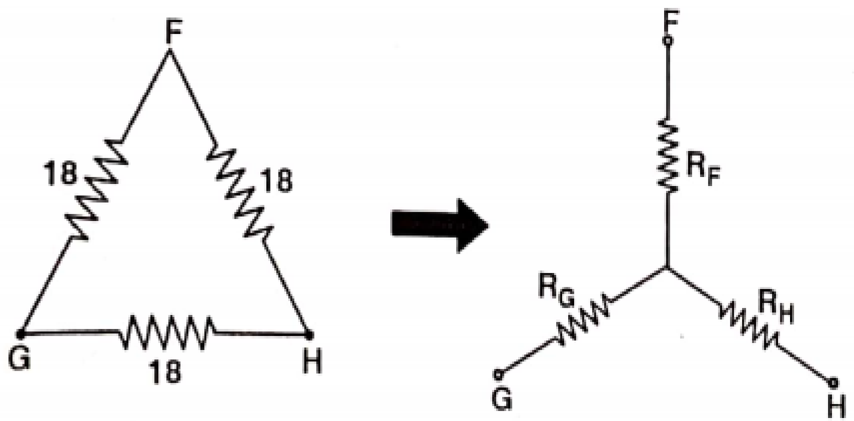


The two delta network (21, 21, 21 and 18, 18, 18) can be converted into star Δ-Y conversion (21,21,21)



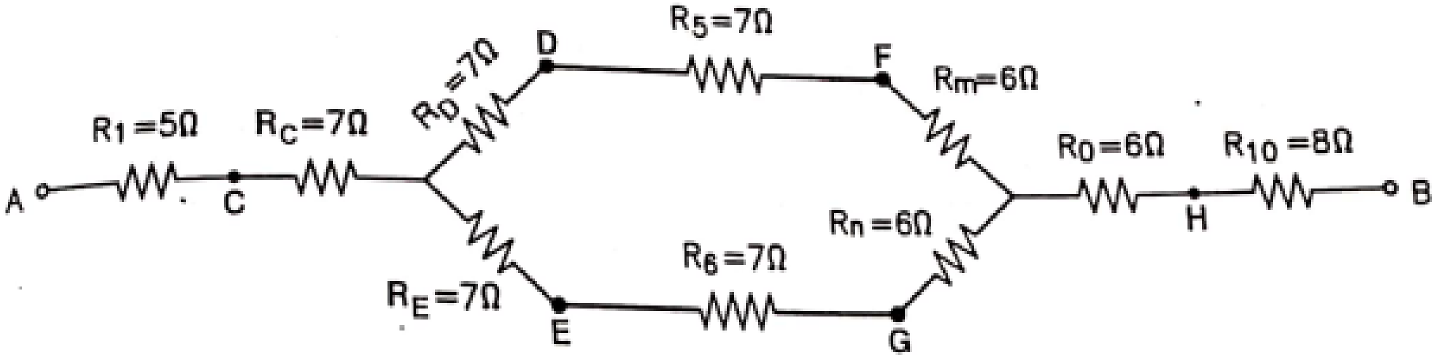

$$R_C = \frac{R_2 \times R_3}{R_2 + R_3 + R_4} = \frac{21 \times 21}{21 + 21 + 21} = 7\,\Omega$$

Similarly $R_D$ & $R_E$ can be found which are also $R_D = 7\,\Omega$ & $R_E = 7\,\Omega$

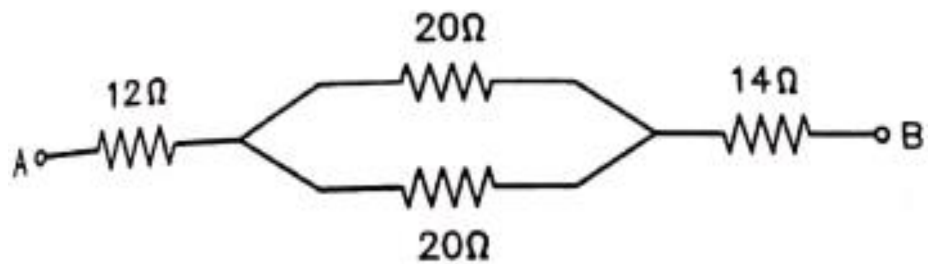



$$R_F = \frac{R_7 \times R_8}{R_7 + R_8 + R_9} = \frac{18 \times 18}{18 + 18 + 18} = 6\,\Omega$$

Similarly $R_G$ & $R_H$ can be found which are also $R_F = 7\,\Omega$ and $R_H = 7\,\Omega$, So the circuit becomes like.




So the circuit between A & B Becomes





So the resistance between A & B is 36 Ω

$$\boxed{R_{AB} = 36\ \Omega}$$